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The SWANSURF Wave Model: Implementation and User Manual

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ABSTRACT

This report describes the implementation and usage of 'SWANSURF', a graphically-driven program for the modelling of waves and surf conditions in the littoral, in support of amphibious operations. The program is based on a coupling of the SWAN (Simulating Waves Nearshore) model developed by the Delft University of Technology and the SURF model (or the Navy Standard Surf Model) developed by the US Navy. The Graphical User Interface provides a platform that allows the user to easily enter inputs, run the coupled models, view the results and forecast the potential impacts of the conditions on amphibious and other littoral operations.

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Executive Summary

A capability to provide detailed, accurate forecasts of the wave and surf conditions prevailing in the littoral is an important factor in the success of amphibious landings and other shallow-water operations. In particular, knowledge of surf parameters allows commanders to make assessments concerning the choice of beach landing site, optimum landing time frame, and choice of craft so that casualties, both craft and personnel, are minimised. Not only can surf and wave models be used in an operational context, they can also play an important role from an engineering perspective. For instance, they can be used when designing new amphibious systems and vehicles. SWANSURF was written to provide the Royal Australian Navy (RAN) with a single, user-friendly, graphically-driven tool that has the capability to adequately model both the nearshore zone and the surf zone accurately, along with its potential impacts on amphibious operations, something that was not available at the time of writing. This report describes that tool, which is maintained as a DSTO research facility, and the core models and interface designs, which have also been implemented by Royal Australian Navy Directorate of Oceanography and Meteorology (DOM) as a component of an operational command decision aid.

This document describes the development, implementation and usage of the SWANSURF program. The basis of SWANSURF is a coupling of two existing models, Simulating WAves Nearshore (SWAN) and the Navy Standard Surf Model (SURF), to produce a combined wind-wave and surf forecasting tool. Given appropriate inputs, the coupled model predicts the wave and surf conditions prevailing in a small area (up to 25 km in easterly and northerly extent) in detail, as a function of both geographical location and time. The two component models are linked together by interface code that converts the outputs of SWAN to the inputs of SURF and then invokes it automatically; this enables rapid and accurate forecasting of surf zone conditions on the basis of the conditions prevailing in the open ocean, in a manner that is transparent to the user. The SWANSURF program is driven by a graphical user interface, which simplifies the processes of setting up the required input files and displaying the resulting information in graphical formats that are easily interpreted.

Sections of this report provide an overview of the coupled SWANSURF model; describing its theory, usage, application, and limitations. Considerable efforts have been made to reduce the complex inputs required by the component models to the few inputs that are most critical and that are likely to be available to the operator. In order to function, the model requires accurate measurements or forecasts of winds, tides, bathymetry and topography. Availability of these inputs is the major operational limitation of the model.

Contents

1. Introduction

Wave and surf conditions in the nearshore zone play an important role in many naval operations and particularly so in amphibious operations; they affect the ability of an amphibious task group to load and transfer materiel and personnel at sea, the ability of ships and landing craft to transit to shore, and the ability of vessels of all kinds to load and unload while on-shore. The capacity to predict the conditions that are likely to prevail at specified locations and times is important to operational decision makers. Knowledge of surf parameters allows commanders to make assessments concerning the choice of beach landing site, optimum landing time frame, and choice of craft so that casualties, both craft and personnel, are minimised. Wave and surf models also play an important role from an engineering perspective. For instance, they can be used when designing new amphibious systems and vehicles. To achieve these objectives, accurate, reliable and rapidly-executing models are required that predict a wide range of wave parameters from the surf zone to a considerable distance offshore.

This document describes a Graphical User Interface program, 'SWANSURF', which provides a user-friendly interface to a coupling of two existing models, Simulating WAves Nearshore (SWAN) and the Navy Standard Surf Model (SURF), to produce a combined wind-wave and surf forecasting tool. SWAN models the two-dimensional wind-wave field, and SURF propagates an offshore wave spectrum onto the beach to produce forecasts of surf conditions. The coupled model (SWANSURF) predicts the wave and surf conditions prevalent in a particular area, given wind, tide, bathymetric and topographic data. SWANSURF was written to provide the Royal Australian Navy (RAN) with a single, unified tool that has the capability to adequately model both the nearshore zone and the surf zone accurately, along with its potential impacts on amphibious operations, something that was not available at the time of writing. Although primarily intended as a developmental package, the present model could be used operationally as a standalone tool. The core routines and the design of the interface have been included in GIS-based command decision aids that are now fielded operationally by the Directorate of Oceanography and Meteorology [Woodham 2005].

The SWANSURF model is driven by a graphical user interface which makes the model easy to use, both in terms of setting up the required input files and in terms of displaying the resulting information in graphical formats that are easily interpreted and understood. The underlying models are linked in such a way that their operation is automated – there is no requirement for the user to manually construct inputs for either model, and SURF is invoked automatically when SWAN terminates.

The purpose of this report is to provide an overview of the SWANSURF model; describing its theory, usage, application, and limitations. Section 2 of this report presents a brief description of the two stand-alone models SWAN and SURF and the reasons why these particular models were selected. Section 3 provides an overview

explanation of the SWANSURF model – the assumptions made and a user manual. Section 4 offers a discussion of potential future enhancements to the model.

2. Wave Forecasting Models

Brief descriptions of the two models SWAN and SURF follow. Refer to the individual manuals for each of these models for more detailed information ([Booij *et al.* 2004] for SWAN, and [Osieki *et al.* 2002a, 2002b] for SURF).

2.1 Simulating WAves Nearshore (SWAN) [Version 40.41]

Simulating WAves Nearshore, or SWAN, is a numerical wave model developed by the Delft University of Technology, Netherlands. Given wind and seabed conditions in the study area and the wave spectra and currents at the edges of the study area, it computes various wave parameters, particularly for small-scale coastal areas with shallow waters.

A number of wave propagation processes are encompassed by SWAN, such as refraction and shoaling due to spatial variations in bottom conditions and currents, and blocking and reflections due to opposing currents and obstacles. Generation and dissipation processes are also considered, such as local wave generation by wind, dissipation by bottom friction, depth-induced wave breaking, whitecapping, and wave-wave interactions. ([Booij *et al.* 2004] p3)

SWAN can be run in either stationary mode or non-stationary (dynamic) mode. In stationary mode, the model runs with fixed boundary conditions, terminating when it has evolved to a steady or 'fully developed' state. Non-stationary mode allows the boundary conditions to change with time – it is essentially a succession of stationary runs, where the output wave conditions of each run provide the input wave conditions for the next. Wind and tidal height variations are supplied by the user. Stationary runs are valid for waves whose transit time through a region is small when compared to the timescale of change in the conditions (for example, winds or tides) of the area through which they pass ([Booij *et al.* 2004] p3).

The primary use of SWAN is as a coastal wave prediction tool and the operating instructions of earlier versions of SWAN stipulated that it should not be used at scales greater than approximately 25 kilometres or to analyse areas where, in a distance of a few wavelengths, changes in wave height are large [Holthuijsen *et al.* 2000]. This restriction has been removed in the latest version of SWAN, primarily to allow the user to nest SWAN in deep water oceanic models such as WAM or Wavewatch III. SWAN is not as effective as WAM or Wavewatch III for oceanic scales. Previous SWAN models

used Cartesian coordinates (Eastings and Northings) and could not be nested in WAM or Wavewatch III which use spherical coordinates.

Although SWAN produces many output variables, the user can choose which of those outputs are to be displayed in the SWAN output reports. Output can be produced for an arbitrary point, line, curve, or area within the modelled area.

To obtain more detail about the SWAN model, including its theory, assumptions, capabilities, limitations, and options, refer to the SWAN manual [Booij *et al.* 2004]

2.2 Navy Standard Surf Model (SURF) [Version 3.1]

The Navy Standard Surf Model, or SURF, was developed for the US Navy in the late 1980s. It arose from the operational requirements outlined in the *US Joint Surf Manual* [COMNAVSURFPAC/COMNAVSURFLANT 1987] and has been used continually since then to satisfy those requirements.

The primary focus of the model is to provide local surf and longshore current forecasts to enable operators of amphibious watercraft to make decisions concerning the viability of performing certain military operations given the prevalent environmental conditions ([Osieki *et al.* 2002a] p5). It is based on the work of Thornton and Guza [1983, 1986], who were responsible for developing numerous models for random wave processes; in particular, breaking wave probability distribution hypotheses.

Unlike SWAN, which has the ability to perform forecasts on a two-dimensional region, SURF carries out its computations on a one-dimensional line perpendicular to the beach. This is appropriate for models that predict wave breaking [Earle 1999]. The reason for this is that wave breaking is determined by local depth. Specifically, when waves enter waters where the depth is less than half their wavelength, their wavelengths will decrease while their wave heights will increase. When the wave height to water depth ratio becomes greater than 0.78, the wave will break.

Basically, the SURF program numerically solves the steady-state energy balance equation. This equation describes the dissipation of energy due to wave breaking, bottom friction, turbulence and wave-current interaction. The model calculates wave energy, and, in turn, wave heights stepwise at a sequence of distances starting from an offshore point and moving in towards the beach.

Breaker type percentages are calculated through the surf zone based on a probability distribution of breaking waves. This distribution is derived from the effect of bottom slope as well as the breaker height and period.

Being a one-dimensional model, SURF incorporates a number of approximations. Namely, SURF assumes that linear wave theory is applicable, that bottom contours are

straight and parallel, that currents do not vary with depth, that wave heights are Rayleigh-distributed, and that directional wave spectra are narrow-banded in frequency and direction ([Osieki *et al.* 2002a] p. 5).

The information required to run the SURF model is a depth profile, a directional wave spectrum at the offshore point, and refraction and shoaling coefficients. These may be either externally provided by the user or internally generated by SURF.

The SURF model outputs a number of forecast surf parameters for a user-specified approach to the beach. Among SURF's outputs are the maximum and significant breaker height, percentage of breaking waves, wavelength, and the longshore littoral current. SURF also provides an estimated percentage of breaker wave types - namely, spilling, plunging, and surging waves - that are present for the chosen beach approach under given conditions. Furthermore, SURF calculates the Modified Surf Index (MSI). The MSI is a single number that summarises the surf zone conditions – the higher the MSI, the rougher the environment [COMNAVSURFPAC/COMNAVSURFLANT 1987].

Refer to [Osieki *et al.* 2002a] and [Osieki *et al.* 2002b] to obtain greater detail on the theory behind the SURF model, as well as its available options and examples.

2.3 Reasons for Using and Coupling the Two Models SWAN and SURF

A DSTO study of models for wave prediction [Andrew, 1999] found that no single model predicted both nearshore wave conditions and surf conditions adequately. For this reason, to effectively model surf zone dynamics, including the approach towards the beach, DSTO elected to combine a nearshore wave model and a surf zone breaking wave model to form one forecasting tool. This section explains why SWAN and SURF were the chosen models and, in turn, why these models were coupled into a single application rather than being used as two standalone programs.

2.3.1 Reasons for Choosing the SWAN and SURF Models

In the DSTO study of nearshore wave models (including the 'REF/DIF_S', 'Wave', 'REFRAC', and 'Boussinesq' programs), SWAN was identified as the best model for simulating growing waves in nearshore areas [Andrew, 1999]. In situations where the waves were no longer growing, REF/DIF_S was considered more suitable, since it also modelled diffraction. It should be noted, however, that when the Andrew [1999] study was written, the SWAN version at the time (version 40.01) did not model diffraction. The current version of SWAN simulates diffraction effects. The SWAN code and manuals are freely downloadable from the Delft University of Technology website (http://fluidmechanics.tudelft.nl/swan/default.htm).

The SURF model was the chosen surf modelling program because it has been used extensively in the US since 1988 to assist with the planning of amphibious operations and has been embedded in a number of navy operational systems; for instance, the United States' Tactical Environment Support System (TESS).

While SWAN is a well-tested and accurate model, it has its limitations; particularly in harbours and areas where obstacles are present. The SWAN model was developed for wave modelling of inshore areas. It can model some characteristics of the surf zone but was not developed for that purpose. SURF, in contrast, was specifically developed to model surf zone conditions along a line perpendicular to the beach. SURF does not model the entire area offshore. Therefore, the SURF model has been embedded into the SWAN model as a coupled application to enable the user to gain a better understanding of the complete operational area.

As previously mentioned, SURF derives from the work of Thornton and Guza [1983, 1986], who modelled energy dissipation based on a Rayleigh distribution of wave heights. Although SURF is a one-dimensional model, it is effective in modelling the surf zone and wave breaking. The reason for this is that wave breaking is predominantly determined by local depth.

SURF outputs a number of parameters that are pertinent to an analysis of the surf zone which are not calculated by SWAN. These SURF parameters are particularly important for amphibious operations. In fact, the SURF model was specifically designed to meet the operational requirements as expounded in the US *Joint Surf Manual* [COMNAVSURFPAC/COMNAVSURFLANT 1987]. Among these parameters is the Modified Surf Index (MSI). This is a single dimensionless number summarising the surf conditions in a particular location, taking into account all the environmental factors. The MSI is calculated based on the highest significant breaker height occurring in the surf zone and the maximum longshore current, along with the breaker type, breaker angle, and the wave period. (For further discussion of the MSI's importance in military operations, refer to section 3.4.4.) The surf zone width and number of surf lines (that is, waves in the surf zone) are also determined. The surf zone width is the distance from the water's edge to the furthest point out to sea where waves start to break (Figure 1). Large surf zone widths can have a negative effect on amphibious operations. The number of surf lines is given by the surf zone width divided by the dominant wavelength.

SURF also calculates the percentage of different breaker types; that is, the proportion that are spilling, plunging, or surging. Knowing which breaker types occur on the beach under investigation is extremely important. For instance, spilling waves are predominantly characteristic of gently sloping beaches and are the preferred breaker wave type for the successful implementation of amphibious operations in terms of minimum casualties (both personnel and landing craft). In contrast, plunging breakers usually emerge on steep beach gradients and result in a forceful and rapid release of energy making amphibious landings difficult and dangerous (although still possible)

with potential risk to craft. Surging breakers predominate on beaches that are extremely steep, almost vertical. Essentially, these breakers hit the beach as a wall of water with wave crest and base arriving at the beach at the same time. The passage of such a breaker is equivalent to a rapid rise and fall in water level. As a consequence, maintaining landing craft in position (for activities such as unloading) becomes very difficult or more usually, impossible.

Not only is the type of breaking wave important, but so too are the breaker height and the angle of the breakers with respect to the shoreline. The SURF model outputs both the maximum and significant[1] breaker height. If the breaker height is high enough, the wave may break on the stern of the landing craft as it lands or withdraws from the beach. Therefore, the craft may become filled with large amounts of water and swamped. The breaker angle is important because it may lead to the craft having difficulty remaining on course and, as a result, it may land at the wrong site. Alternatively, the craft may be propelled parallel to the beach, thereby becoming grounded. The SURF program also tells the operator the direction of the breaker measured relative to a perpendicular approach towards the beach (left or right flank) as viewed by an observer at sea. Figure 1 shows waves heading towards the left flank as seen by an observer on the landing craft. Also shown on the diagram is how the breaker angle is measured. If the waves were travelling parallel to the shore, then the breaker angle would be zero degrees.

All the surf parameters considered above can have a critical influence on the success of an amphibious operation in terms of both personnel and craft safety, as well as optimum deployment of the available landing craft. A more extensive discussion of surf parameters can be found in [COMNAVSURFPAC/COMNAVSURFLANT 1987].

By performing different SURF runs that consider approaches to a number of alternative landing sites, the SURF model enables the operator to decide which beach to land on, what the best approach to that beach is, and which craft to use.

[1] The significant breaker height is the mean height of the highest third of the distribution of heights

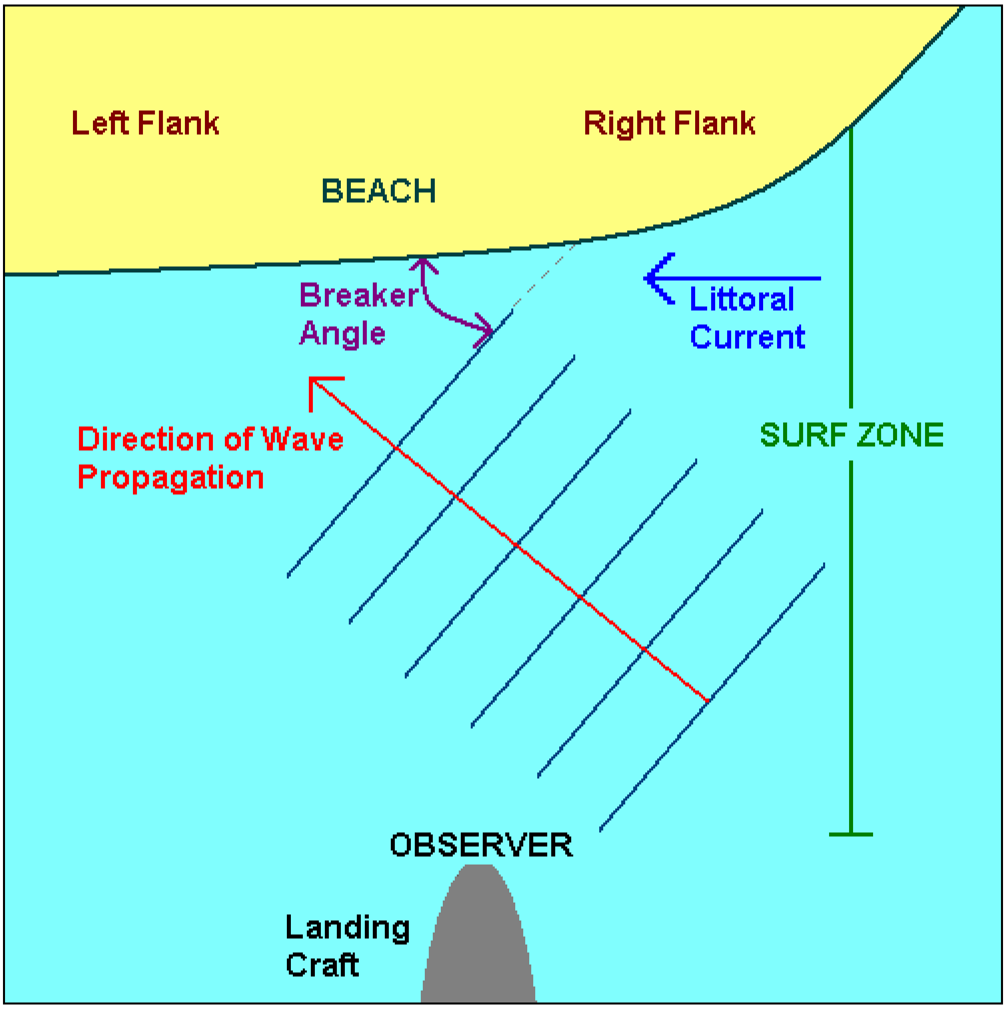


Figure 1: Selected surf zone parameters.

2.3.2 Reasons for Coupling the Two Models into One Forecasting Tool

Although the SURF model provides the information needed to ascertain the feasibility of amphibious operations as well as general information regarding the surf zone, it was nested as part of a SWAN run, rather than being used as a standalone model, for a number of reasons.

Firstly, the SWAN model outputs a wave spectrum file. Data from this spectrum file can be used as input to the SURF model. Although SURF has the option of generating a wave spectrum internally from two input wave parameters (for the dominant sea and the dominant swell), the SWAN model allows the user to combine multiple wave inputs and this gives a more accurate picture of the conditions prevalent in the area under investigation. Directional wave spectra, which depict the distribution of wave energy in terms of frequency and direction, are the primary input of the SURF model.

Therefore, providing a spectrum that contains inputs from more than two waves (and from at least one wind wave and one swell wave) should produce more accurate results.

Secondly, SWAN allows for tidal effects. The model allows the user to input both time- and spatially-varying tides. Therefore, the spectral outputs produced by SWAN and subsequently used as inputs to SURF implicitly include the effects of tides. This is important, because tides influence the breaker height, and they can also have a significant effect on the nature and width of the surf zone.

Thirdly, coupling the models makes the operation of the programs easier for the user. Rather than running SWAN and manually extracting the relevant data and formatting it into the appropriate SURF input file format, it is much easier and more convenient to have an additional, DSTO-supplied module to do this automatically. In particular, SWAN can produce wave forecasts at predetermined time steps. Direct coupling allows time series of both inshore wave fields and surf parameters to be routinely output. By nesting SURF in SWAN, the SURF model can be automatically called by the SWAN model at each time step and all the required input files can be set up automatically. Run by itself, the SURF model would require the user to set up all the input files at each time step manually, because the SURF model cannot be run continuously for a number of time steps. This becomes very tedious.

The fourth reason to nest SURF into SWAN to obtain one forecasting tool is that by coupling the two models, more realistic simulations of amphibious operations and strategies can be made over extended areas. Although SURF provides a number of useful outputs, it is a one-dimensional model and only produces data along a particular line approaching the beach. Since SWAN is a two-dimensional model, it provides forecasts over a much larger region, extending from the coast into deeper water, thereby giving the operator a visualisation of the total area of operation, rather than just a limited portion of it. Also, SWAN calculates a variety of different wave parameters (see section 2.1) that are not computed by SURF.

3. The SWANSURF Forecasting Model

3.1 Description of the SWANSURF Model

As previously mentioned, the forecasting model is a single application that links the SWAN and SURF models. The main task in formulating the coupled model was to convert the SWAN output to the input format used by SURF. Very few modifications were made to the original models. Rather, additional Fortran subroutines were created which converted the relevant SWAN output into SURF input files.

To run the SURF model, an input file is required with the parameters shown in Figure 2 (refer to the SURF manual for more details [Osieki *et al.* 2002a]).

Line	Description	Units	Range
1	Input File Name	-	-
2	Date and Time (YYYYMMDDHH)	-	-
3	Landing Zone Name	-	-
4	Input Depth Profile File Name	-	-
5	Input Wave Spectrum File Name	-	-
6	Input Wave Refraction File Name	-	-
7	Compass Heading Toward Beach	Degrees	0 - 359
8	Slope / Sediment Type	-	1 - 10
9	Starting Depth	Feet	> 0
10	Offshore Wave Spectrum Depth	Feet	> 0
11	Sea Wave Height Sea Wave Period Sea Wave Direction Swell Wave Height Swell Wave Period Swell Wave Direction	Feet Seconds Degrees Feet Seconds Degrees	> 0 1 – 30 1 – 359 > 0 1 – 30 1 – 359
12	Wind Speed Wind Direction Tide Elevation	Knots Degrees Feet	> 0 0 – 359 + or -
13	Output Data Grid Spacing	Feet	> 0 and < 10

Figure 2: The contents of the SURF Input File (.in)*

The input file name is taken to be the project name with an '.in' file extension. The date and time field was extended to include minutes (mm) and seconds (SS); specifically, YYYYMMDD.HHmmSS. The landing zone name was arbitrarily chosen to be 'SURF Zone'.

SURF allows the user to input either a depth profile along a perpendicular approach to the beach (the 'surf transect') or a beach slope-indicating sediment type (for example, boulders, coarse sand). SWANSURF uses depth data from a combined bathymetry / topography file to produce the depth profile file required by SURF. Consequently, the slope or sediment type line in the input file (line 8) is left blank, while line 4 contains the name of the depth file. The input depth profile file name is *.dep where * is the project name.

Similarly, the user can input either a spectrum file containing the required wave data or single numbers for the sea wave height, period and direction and the swell height, period and direction. The coupled model selects the former. Hence, line 11 of the input

file is left blank. The input wave spectrum file name is written in line 5. It is just the project name with the extension '.spc'.

The starting depth is input as zero. This means that SURF does not use the self-start option. Hence, calculations are performed starting at the point stored in the depth profile file that is farthest offshore. As a result, a potential error caused by excess energy dissipation associated with the wave breaking probability (Rayleigh) distribution used by the model is avoided, as calculations are started well outside the surf zone [Earle 1999]. (Note that if the self start option were to be used, then the offshore wave spectrum is shoaled and refracted to the starting depth specified [Osieki *et al.* 2002a], resulting in reductions in both model run time and quantity of output data. This option was not used since the SURF model run time is not excessive.) The offshore wave spectrum is located on the surf transect at the most distant point from the beach. The SWANSURF model ignores all refraction effects in the surf zone so line 6 contains the word 'none'.

Other parameters required as input to the SURF model include the compass heading of the surf transect towards the beach, wind data and tide data. The compass heading is calculated in a subroutine using the formula:

$$CompassHeading = \cos^{-1}\left(\frac{\sin(latitude2) - \sin(latitude1) * \cos(dist)}{\sin(dist) * \cos(latitude1)}\right)$$

where *dist* is the great circle distance (measured in radians) between the two points. As was the case for the spectrum file, the wind speed and direction are calculated from data at the point that is furthest offshore. All other directions (for example, wind direction and wave direction) are measured relative to True North.

All SURF input data is taken from the SWAN one-dimensional output table '*_SWAN1D.tab', where '*' is the project name. It should be noted that the depth in this table is depth of the seabed relative to the bathymetric height datum, plus the level of the tide above that datum. Therefore, to prevent the double addition of tides, the tide elevation is set to zero in the SURF input file. Tide is included as part of the bottom profile rather than as a separate variable which is added on by the SURF program, because the SWAN program allows for spatially-varying tide data, whereas the SURF program assumes the tide level is constant at each point along the surf transect. The extra information leads to more accurate results.

The final piece of information required to form the SURF input file is the output data grid spacing. This is automatically calculated by the coupled model and is based on the length of the surf transect. The grid spacing cannot exceed 10 feet (approximately 3 metres).

Note that the SURF model uses feet and knots in the input file and also to perform all its calculations whereas SWAN uses metres and metres per second. The subroutines

convert the SWAN outputs to the appropriate units as required by the SURF program. SURF output is then converted back to metres and metres per second.

A depth profile file is also created from the SWAN data, as shown in Figure 3. The format for the depth profile file as described in the SURF manual states that distances offshore are to be positive while distances onshore are to be negative. Since the SURF code itself does not impose this limitation, SWANSURF takes all distances to be positive measured from the first available point onshore for coding simplicity. Also, it is not important whether depths are entered in the depth profile from onshore to offshore or vice versa, since SURF is programmed to reorder the depths where necessary.

Line	**Description**		
1	Depth Profile File Name		
2	Distance Units 1 – feet 2 – metres 3 - yards		
3	Depth Units 1 – feet 2 – metres 3 – yards		
4 to end of file	Index	Distance	Depth [Depths (+) Elevations (-)]

Figure 3: SURF Depth Profile File (.dep)*

SURF 3.1 allows the user to enter a maximum of 500 depth profile data points. Since the maximum output grid spacing is approximately 3 metres, the maximum length of the line along which SURF performs its calculations is only 1524 metres. In SWANSURF this length is extended to 3000 metres, to enable the operator to gain a better understanding of the prevailing conditions along the approach towards the landing site from greater distances offshore. Therefore, the surf transect can now contain more than 500 data points; however, the maximum output grid spacing has been preserved.

SWANSURF uses a file to input the wave parameters required to run the SURF program. The data is taken from the spectrum file produced as SWAN output and has the form shown in Figure 4 (adapted from [Osieki *et al.* 2002a]). This SURF spectrum file, *.spc, is created from the SWAN output spectrum file, *_SWANSpec.out (where '*' is the project name).

Line	Description	Units	Range
1	Spectrum File Name	-	-
2	Number of Angles	-	1 - 180
3	Number of Directions	-	> 0
4	Number of Frequencies	-	1 - 50
5	Initial Direction	Degrees	1 - 359
6	Width of Direction Bin	Degrees	2 - 180
7	Direction of Waves 1 = Direction waves are coming from 2 = Direction waves are going to		
	Directional Wave Spectrum *(This section is repeated for each Frequency Bin)*		
	Bin Number	Integer	1 - 50
	Lower Limit of Frequency Bin Centre of Frequency Bin Upper Limit of Frequency Bin	Hertz Hertz Hertz	>= 0 >= 0 >= 0
	Directional Wave Spectrum	$\frac{\text{Metres}^2}{\text{Hz * rads}}$	>= 0

Figure 4: SURF Wave Spectrum File (.spc)*

Not only were Fortran subroutines created to convert the SWAN output data to SURF input data, but the SURF program itself was set up as a subroutine of the SWAN program. The coupled model runs the SWAN model at fixed time steps specified by the user. At the completion of each time step, the output produced by SWAN is converted to SURF input and the SURF subroutine is invoked, as shown in Figure 5.

Due to the complicated nature of the SWAN input file, producing it is a laborious task and requires the user to have an understanding of wave modelling. Therefore, to make the coupled SWAN and SURF model useful in the field, it was necessary to make the coupled model user friendly and easy to understand. A previous Graphical User Interface (GUI) was generated by Hamilton [2001] to simplify the inputs to the SWAN model. Those simplifications have also been implemented in the GUI described herein. Consequently, to run the coupled model, the user requires minimal knowledge of nearshore wave processes. Inputs to the SURF model are automatically obtained from the outputs generated by SWAN. The inputs required from the user are discussed in the following section.

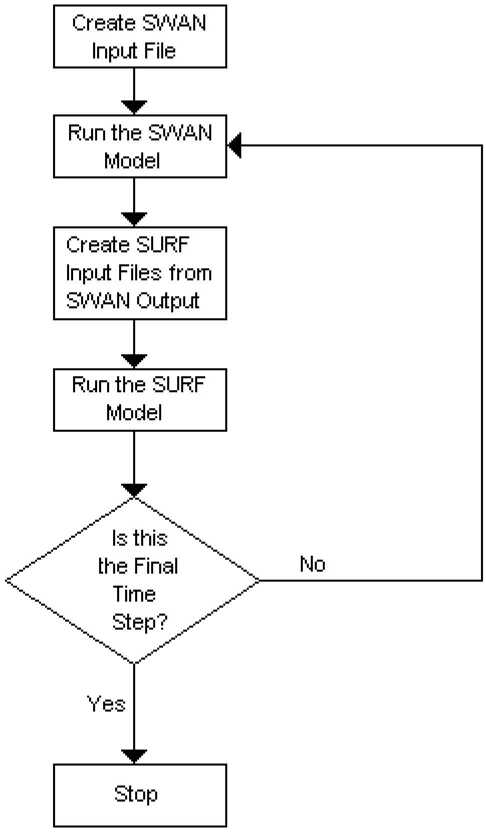


Figure 5: The SWANSURF calling sequence.

3.2 Input Requirements: Model Assumptions and User Options

SWANSURF requires a number of inputs from the user. Most of these are inputs to the SWAN model. A GUI was set up in Visual Basic to simplify the creation of this input file [Hamilton 2001]. This GUI has now been substantially upgraded and modified to include the SURF model, an output viewer, and displays of Royal Australian Navy hydrographic charts. The map display facilitates easy selection of the area of interest and the input of a line extending from the surf zone to a landing point on the coast along which SURF output is required.

To set up a SWAN input file, the user must select 'Create SWAN Input File' from the 'Options' menu or alternatively, click the  icon. The multi-page form that subsequently appears allows all inputs required to run the SWANSURF model to be entered. Considerable care has been taken to trap user errors in the data-entering phase of the project. When invalid data has been entered into any of the input fields of the GUI, the font for that input turns bold and red. Correct data is displayed in black text. Pointing the mouse at a text box without clicking displays the valid range of values for

that data element. Furthermore, when all required data has been keyed into a tab correctly, its corresponding 'light' in the 'Input Checklist' frame turns green; otherwise the 'light' is red.

Firstly, a project name and location are required. To do this, either type the details directly into the appropriate text boxes on the form, or press the 'Choose Project Name and Location' button. Pressing this button will bring up an Explorer™ style file manager. Simply choose a directory and folder where the project files will be stored or alternatively create a new directory and/or folder. Type the project name in the 'File name' text box and then click 'Save'. Due to the number of output files produced by the coupled model, it is recommended that a new folder be created for each project.

The SWAN model requires the bounding coordinates of the area under investigation. By clicking on the 'Area Coordinates' tab (Figure 6), the user can define a rectangular box within which SWANSURF performs its calculations. The SWANSURF model uses spherical coordinates (geographical latitude and longitude coordinates in degrees) as opposed to Cartesian coordinates (grid locations in metres relative to user defined x- and y-axes). The reason for this is that Cartesian coordinates are only valid for small areas, whereas spherical coordinates can be used for both large and small scales. Spherical coordinates are also easier to work with when dealing with geographical data.

Required inputs for the 'Area Coordinates' tab are the longitude and latitude coordinates (in degrees) of the bottom left and top right corners. The grid coordinates can either be entered manually (by typing into the text boxes) or graphically, by drawing a box over the map (that is, clicking the icon and dragging the mouse). The usual 'zoom in', 'zoom out', and 'pan' features are available to the map. The SWANSURF GUI stipulates that this box should be at least 50 metres by 50 metres and at most 25 kilometres by 25 kilometres. Although the current version of SWAN (40.41) [Booij 2004] allows larger areas to be modelled, the recommendation of previous versions of SWAN (40.11) [Holthuijsen 2000] that the grid should not exceed this size is maintained. The reason for this is that SWAN is not as effective when larger areas are used. The dimensions of the area selected by the user are displayed in the Visual Basic interface (Figure 7). The computational area must extend sufficiently far onto the land to account for tides and to enable an approach line to be drawn from offshore to the beach.

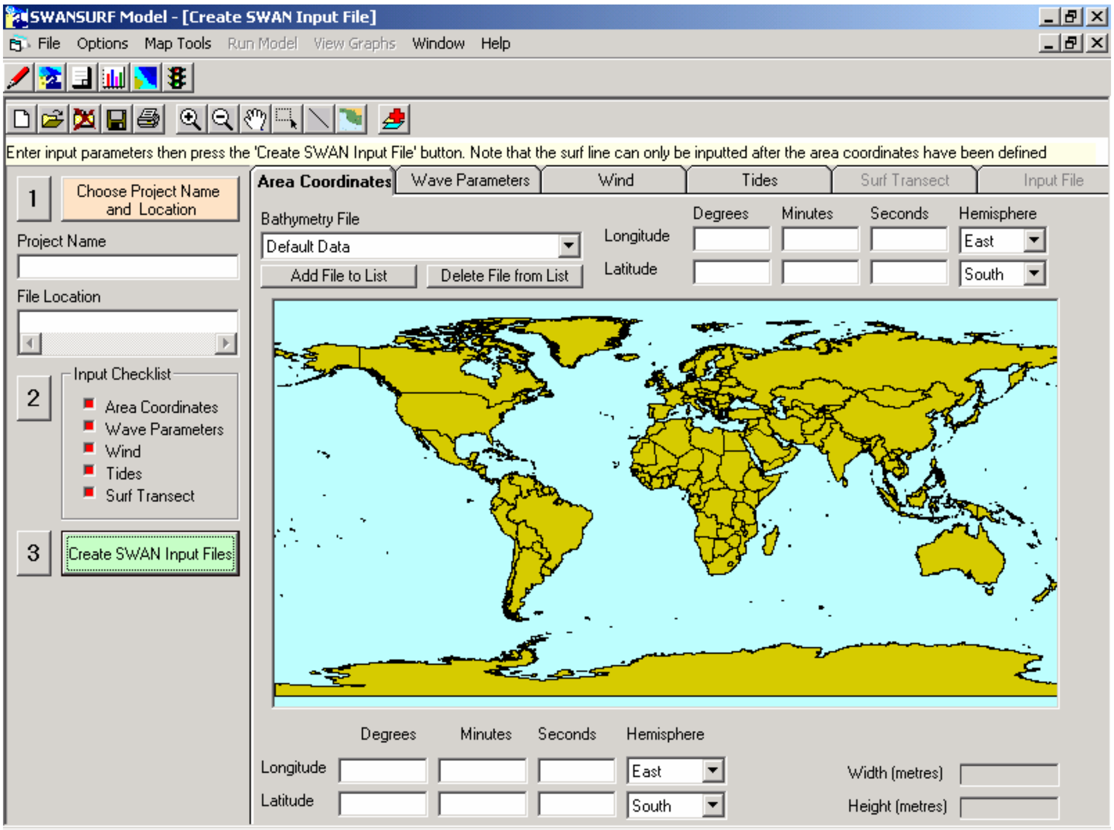


Figure 6: The 'Area Coordinates' tab from the SWANSURF GUI. This is where the user defines the SWAN computational area.

Since the global map included in the GUI is only a low-resolution vector outline of the coast, the GUI enables the user to load map images (for instance, SeaFarer Geotiffs) to obtain a more accurate representation of the area under investigation (Figure 8). To load a map image, choose **Map Tools > Add Map Layer** or click on the icon and select the required file. Some SeaFarer GeoTiffs are already included in the software package. These are indicated by pre-drawn rectangles on the map (Figure 8). To load one of these, simply click on **Map Tools > Click a SeaFarer Tile to Load Chart Image** (or alternatively, click the icon) and then click on the predefined square for the area required.

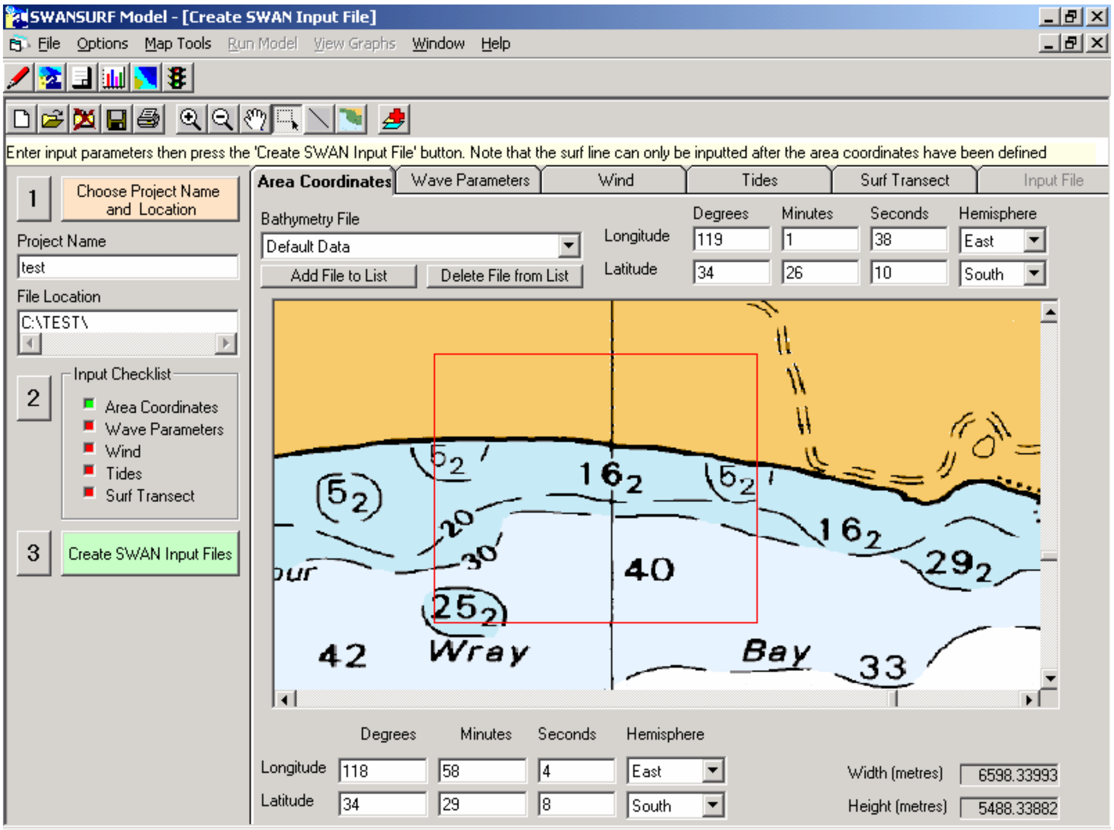


Figure 7: Rectangle showing the chosen SWAN computational area.

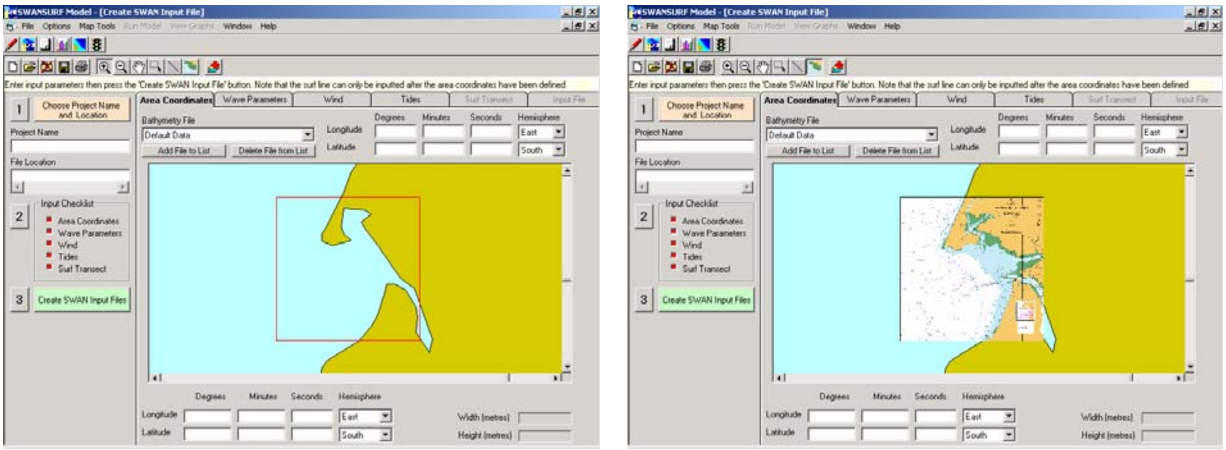


Figure 8: The 'Area Coordinates' tab depicting the pre-drawn rectangle of the preloaded SeaFarer GeoTiff (left). Clicking the appropriate icon and then clicking the rectangle loads the chart (right).

From the computational area chosen, the program sets up a combined bathymetry and topography profile, BathyTopo.bot. (For the format of this file refer to Appendix A.1 Depth Data File (BathyTopo.bot).) The depth data file is created from a gridded bathymetry data file; that is, bathymetry and topography is read from a file that is organised as a grid of latitude and longitude points. Two default bottom data files are included as part of the SWANSURF package:

- For Australian geographical areas (102 to 172 degrees East longitude and -8 to -52 degrees South latitude), a 36 second (approximately 1 kilometre) digital terrain model (DTM) from Geoscience Australia (bathytopo.asc).
- For areas outside Australia, a two-minute DTM (etopo2.dat) from the National Geophysical Data Centre (NGDC).

The quality of the model outputs depends on the resolution and accuracy of the input bathymetry data contained in the BathyTopo.bot file. Since both the included files are fairly coarse, provisions have been made to allow the user to obtain data from other sources if these files contain both bathymetry and topography data and the data contained in them completely covers the area of interest. Since wave action in the surf zone is also influenced by the beach slope, it is crucial that the bottom data file contains both bathymetry and topography data; otherwise the SURF component of the coupled model will not function correctly.

It is also important that the bathymetric/topographic data selected covers an area larger than the chosen wave modelling area, because if there is no data available outside the computational perimeter, SWAN assumes that the data just outside the boundary is equal to that on the boundary, leading to unreliable computations. Therefore, SWANSURF requires the user's bathymetric/topographic data to cover not only the area of interest, but also a two mesh wide margin around that area. If the data contained in the user's data file does not sufficiently cover the area under investigation, then the program will resort to using the default data. If this happens, the user will be alerted by a pop-up message. In general, when defining the area of interest, there is no need for the user to add a margin around their chosen area in order to counteract any edge effects; the GUI will automatically set up a depth data file that meets this requirement.

To choose the relevant bathymetry/topography data file, the user must select it from the drop-down file list. If it does not appear in the available file list, then it will need to be added. This can be done by clicking on the 'Add File to List' button. This will bring up a data entry screen (Figure 9) where the required file details are entered. Note that the 'Bathymetry File Details' screen is where general details of the user's bathymetry and topography data file are entered. It is not where specific details of the desired computational area are input.

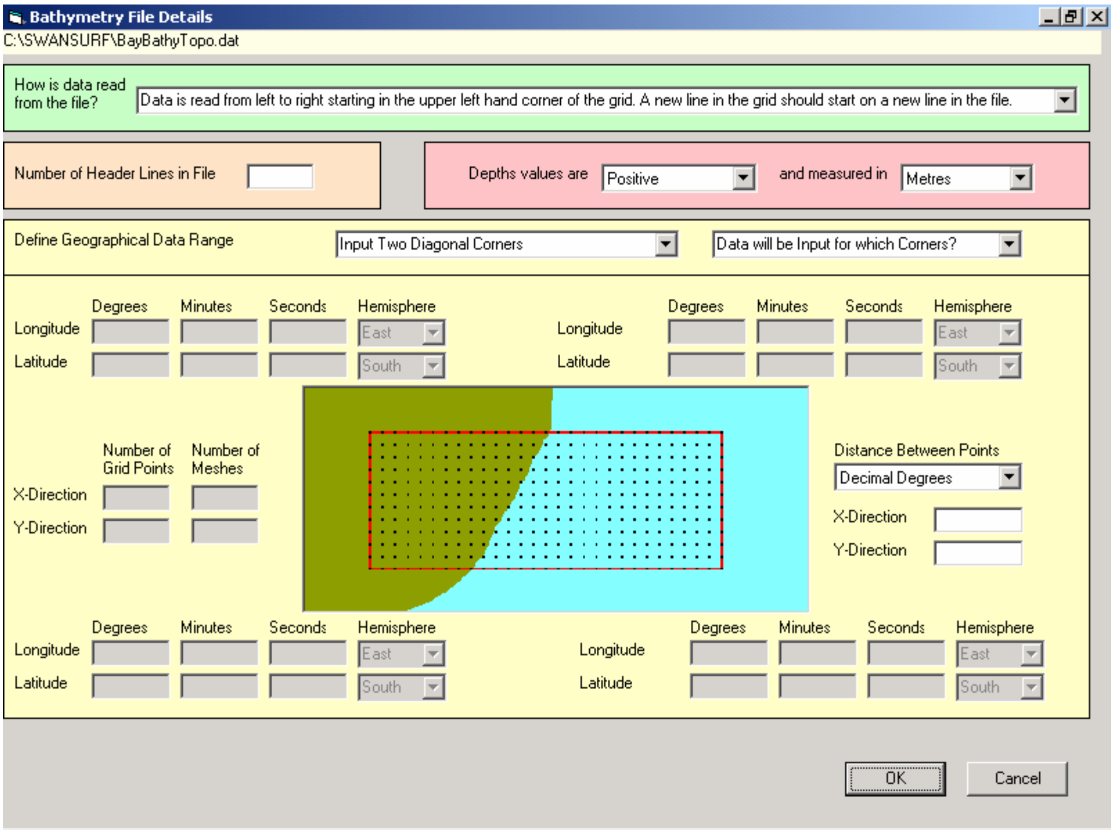


Figure 9: The 'Bathymetry File Details' data entry screen.

In order to add a file to the list, the user must firstly enter the structure of the data file. The available options are shown in the drop-down list. The data in the file must be stored as a grid, which can be read either across the rows or down the columns, starting at either the upper left corner or the lower left corner. The number of header lines contained in the file must be entered. Information is also required regarding the bathymetry data; namely, whether depths are measured as positive values or negative values, and the unit of measurement. The full extent of the bottom data covered by the file (as opposed to the extent of the area of interest) must be specified and this is done in a number of ways:

- Entering the latitude and longitude coordinates of two opposing corners; either upper left and lower right, or lower left and upper right.
- Entering the latitude and longitude coordinates for one corner and the number of grid points in both the x- and y-directions.
- Entering the latitude and longitude coordinates for one corner and the number of meshes in both the x- and y-directions.

The number of meshes is one less than the number of grid points. The distance between the grid points, which is equal to the size of the meshes, must also be defined. The latitude and longitude coordinates and number of grid points or meshes refer to

the full range of data covered by the user's bottom data file as opposed to the latitude and longitude coordinates of the computational area chosen.

Once all the bathymetry / topography data file details have been entered, click 'OK'. The bottom file is added to the available file list and all details in the file are stored in a file *H.hdr where '*' is the user's data file name. This means that the user's bottom data file can be used in future SWANSURF sessions without the user having to re-enter the appropriate file details. Files can be deleted from the file list by clicking on the 'Delete File from List' button in the 'Area Coordinates' tab. Once files are deleted from the list, the *H.hdr file is also deleted. Hence, if the user wants to use the deleted file at some later stage, the file will need to be re-added to the list and this will involve re-entering all the file details.

The 'Wave Parameters' tab contains the options for entering an initial wave field for SWAN. The options are: a single initial significant wave height (between 0 and 10 metres), period (between 0 and 30 seconds), and direction (degrees); multiple initial wave heights, periods, and directions; or wave data from a file (Figure 10).

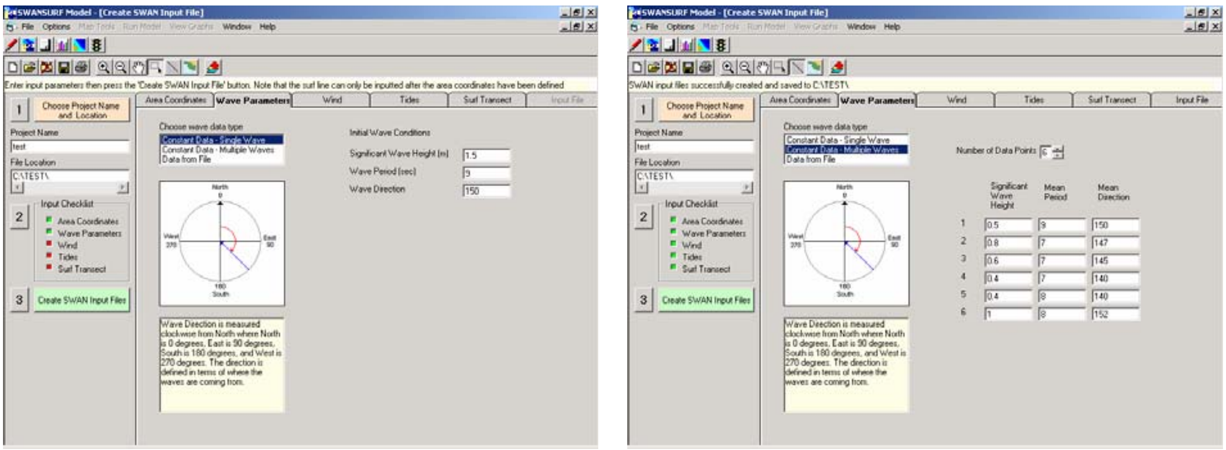


Figure 10 The 'Wave Parameters' input tab. Data can be entered as either a constant value for a single wave (left), a constant value for multiple waves (right), or from a file.

When the multiple wave option is used, the GUI sets up a wave spectrum file (WaveSpecFile.dat) as required by SWAN (see Appendix A.3 Wave Spectrum File (WaveSpecFile.dat)). The wave spectrum encompasses all waves (both sea and swell) impacting on the area of investigation. Since the wave data must be input at each boundary, the spectrum file is copied four times (namely, WaveSpecFileN.dat, WaveSpecFileS.dat, WaveSpecFileE.dat, and WaveSpecFileW.dat) to define the north, south, east, and west boundaries of the area chosen.

Wave data from a file can also be used. This wave data must be in the form of a wave spectrum, as described in Appendix A.3. Wave Spectrum File (WaveSpecFile.dat).

SWAN supports the input of wave data from a WAM output file. Support for this option is yet to be implemented in SWANSURF.

The Nautical convention is used to define the wave direction. This means that the wave direction is the direction from which waves are approaching, with degrees being measured clockwise with respect to zero at geographical North (Figure 11). Therefore, for waves coming from the East, the wave direction is 90 degrees. Waves coming from the South have a direction of 180 degrees and so on.

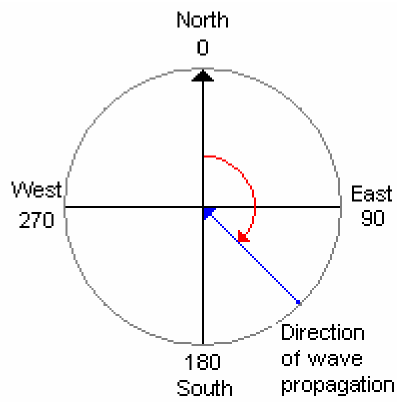


Figure 11: Nautical convention for defining wave and wind direction.

By clicking on the 'Wind' tab, the user can enter the wind data by choosing one of three options (Figure 12). Namely, constant speed (between 0 and 100 metres/second) and direction (between 0 and 359 degrees); time series wind data for a maximum of twelve time steps; or gridded wind data from a file (see Appendix A.2 Wind (WindSeries.dat) and Tide (TideSeries.dat) Files for the required format). Although the wind data will vary for each time step when the time series option for wind is used, it will be spatially constant. Spatially variable wind data for each time step can be input by setting up a wind data file in the required SWAN wind file format. As was the case with waves, SWAN uses the Nautical convention to define wind direction.

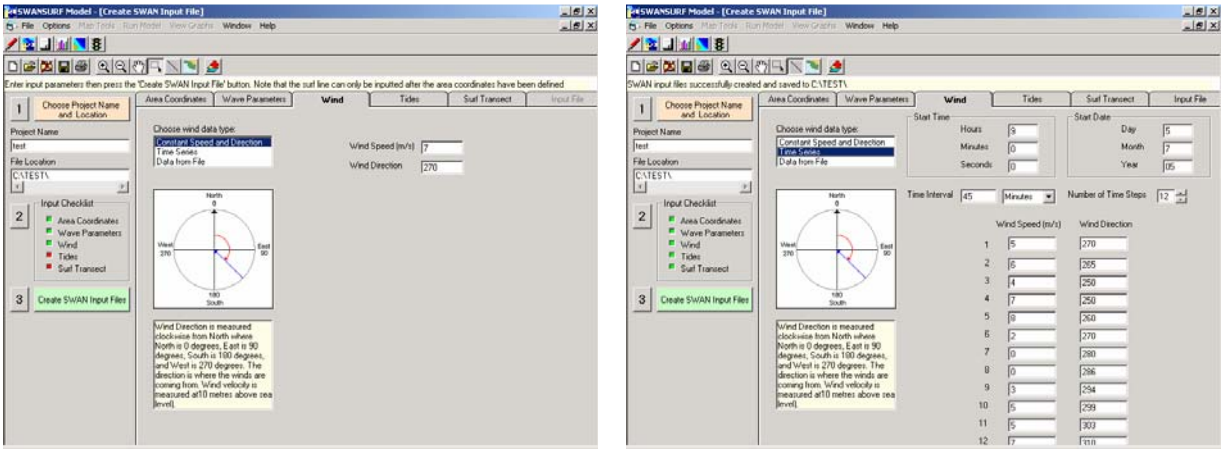


Figure 12: The 'Wind' input tab. Data can be entered as either constant values (left), a time series (right), or from a file.

Similarly, the 'Tides' tab allows the user to enter the tidal height data. Water level is measured positive above sea level relative to the same datum as used by the bathymetry data, and negative downwards. Tidal data can be input as either a constant (between –25 and 25 metres), a time series (with a maximum of twelve time steps), or from a file (Figure 13). Once again, if a time series is chosen, the tide data will be spatially constant for each time step. Spatially variable tide data for each time step can be input by setting up a tide data file in the required SWAN tide file format. For the format of the tide file refer to Appendix A.2 Wind (WindSeries.dat) and Tide (TideSeries.dat) Files.

If a time series is entered for both wind and tide data, the time interval, number of time series points, and start date and time for the two time series do not have to be the same. For instance, the user can set up a wind series having twelve data points starting on the 1st June 2005 at 23:00:00 with computations carried out at 40 minute intervals, while the tide series can begin on the 2nd June 2005 at 04:00:00 with only three data points at hourly intervals. If both a wind series and a tide series are entered, then SWAN will output data based on the wind time series.

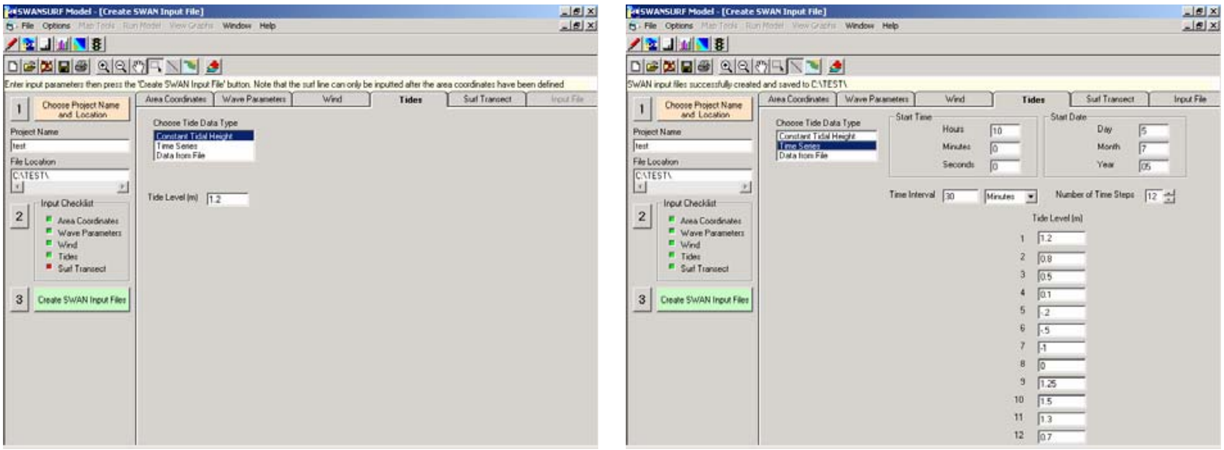


Figure 13: The 'Tides' input tab. Data may be entered as either a constant value (left), a tide series (right), or from a file.

It is recommended that the time step used to run the SWAN model should be small enough so that changes in the wave field and other parameters are well resolved [Booij 2004].

SWAN also gives the user the option of producing output along a predefined section within the area of computation. This predefined section may be a two-dimensional region, a curve or line, or even a point. Since SURF is a one-dimensional model and requires data along a line as input, the GUI was extended to allow the user to enter a line that lies in the confines of the user-defined SWAN computational grid (Figure 14). The SWAN model is able to provide outputs along this line such as the depth, wave, wind, and tide data. It is this output that is used as input to the SURF model. The 'Surf Transect' tab can only be accessed once the 'Area Coordinates' tab data has been entered correctly.

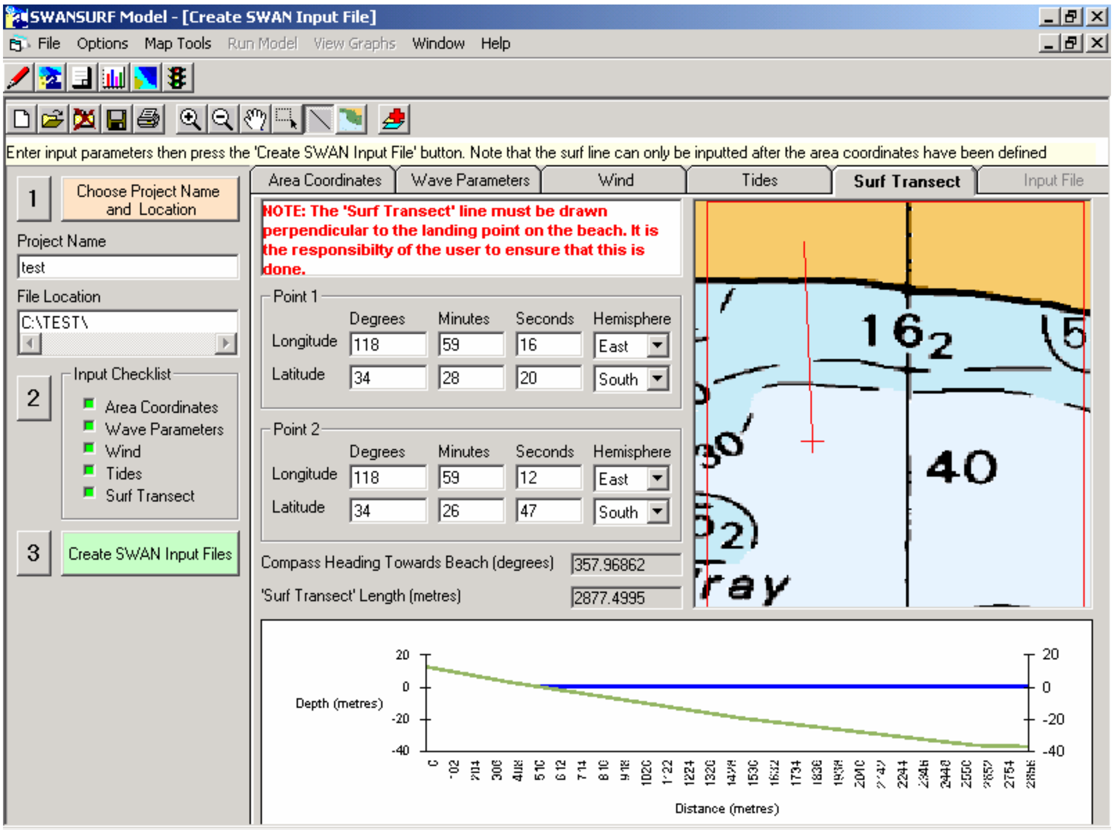


Figure 14: The 'Surf Transect' tab showing the approach to the beach as well as the depth profile along the surf transect.

The only inputs required for the 'Surf Transect' tab are the two endpoint coordinates of the surf transect. The coordinates can be either entered manually or can be defined by clicking on the  icon and then drawing a line on the map.

There are guidelines on how the surf transect should be drawn. The surf transect can be no longer than 3000 metres and must traverse both land and water. For the SURF program to give reliable results, the land elevation must be greater than the highest tidal value plus wave height. Another proviso in accordance with the SURF manual [Osieki *et al.* 2002a, 2002b] is that the surf transect must be drawn perpendicular to the beach. Furthermore, there must be enough points along the surf transect, both onshore and offshore, so that valid SURF runs can be performed. In particular, there must be an adequate number of points onshore to ensure that the topographic height of the surf transect depth profile takes into account the maximum water level impacting on the beach slope. There must also be an adequate number of points offshore to enable a sufficient amount of outputs to be displayed so that an accurate picture of the surf zone may be obtained.

The GUI attempts to capture many of the errors associated with drawing the surf transect such as exceeding the maximum length of the surf transect and ensuring that it includes both land and water. However, not all errors are easy to trap. In particular, errors related to travelling over islands, or raised structures on the sea floor, may not be detected. For this reason, after the SWANSURF program has made all its checks, a graph of the depth profile is evoked to give the user a visualisation and, in turn, a better understanding of the sea floor terrain along the surf transect. The graph enables the user to view the structure of the sea floor to ascertain whether there exist any obstacles that would affect any surf operations. The onus is on the user to ensure that the surf transect is chosen appropriately.

The number of data points along which SURF will produce output is determined automatically by the GUI and depends on the length of the surf transect. The shorter the surf transect, the closer the output points will be.

Once the data has been entered correctly (that is, all 'lights' in the 'Input Checklist' frame are green and a project name and location have been chosen), press the 'Create SWAN Input Files' button. This will create the SWAN input files (see Figure 15 for the standard SWAN input file). Depending on the wave parameter type chosen, the GUI will produce either one or two input files. If 'constant' wave data is chosen, then only the standard input file will be created and SWANSURF will be run based on this input file. When any of the other wave options is chosen, a second input file called the 'hot input file' (*.inh) will also be created. This additional input file is used to drive the standalone SWAN program to create a 'hotfile'. A 'hotfile' is a wave spectrum file that is created by the SWAN program run in stationary mode using multiwave initial conditions and only the first values for the wind and tide data. This 'hotfile' is used as input to a dynamic run of SWANSURF driven by the usual SWAN input file (*.inp) with the *.hot file as the initial wave field.

Simply running the SWANSURF model in dynamic mode with the multiple wave data as an initial condition will cause errors in the first time step because the waves have not had time to fully propagate through the area of computation. Therefore, at the first time step, the initial condition would only be evident at the edges of the computational area; the internal part of the computational area would not show the correct wave characteristics. Using the 'hotfile' ensures that the waves have fully propagated through the area of computation and that the wave field has reached a steady state before the calculations begin for the first time step, thereby producing reliable results.

Pressing the 'Create SWAN Input Files' button not only creates the required SWAN input files but also the files containing the input data in a form that meets SWAN model requirements. What files are created depends on the data input options selected by the user and includes the depth profile file (BathyTopo.bot), the wave spectrum file (WaveSpecFile.dat), the wind series file (WindSeries.dat), and the tide series file (TideSeries.dat). The depth profile file will always be created. The wind series and tide series files are created when the user chooses the time series option and provides

manual inputs for those particular parameters. Four wave spectrum files (one for each boundary of the computational area) are produced when the user chooses the multiple wave option in the 'Wave Parameters' tab. Once formed, these files are automatically saved to the chosen directory. Creating these files may take a few minutes, depending on the size of the SWAN input area and the number of additional files that must be produced. For a more detailed description of the form of the bottom, wind, tide, wave spectrum, and input files, refer to Appendix A: File Formats.

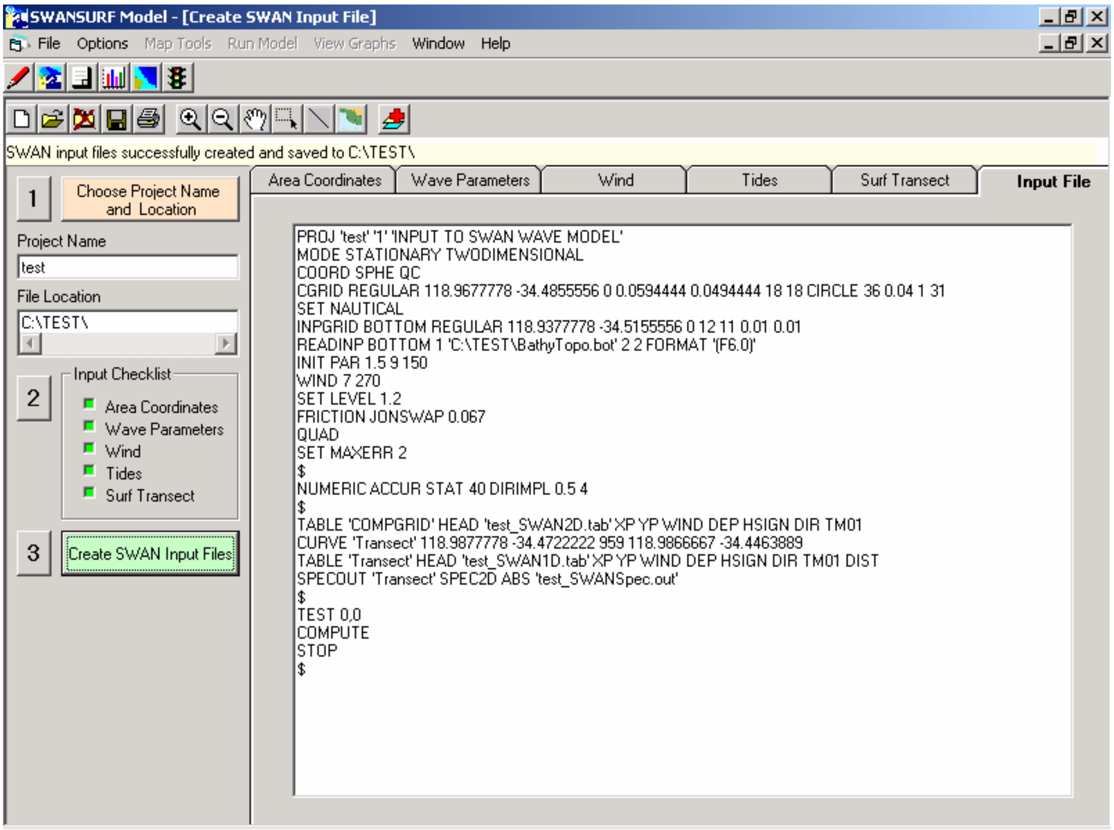


Figure 15: The SWAN input file produced by the GUI after the 'Create SWAN Input Files' button has been pressed.

The GUI also allows the user to save input data by clicking on the save icon ( ) or by choosing **File > Save Data**. This data can then be reopened (click or choose **File > Open Data**) to enable the user to easily make modifications to the inputs without having to re-enter all the data.

This concludes the process of creating the SWAN input file using the GUI. The process described represents a significant simplification of the original SWAN input file setup process. (For more details of the SWAN input file and required inputs refer to [Booij 2004]). As part of the simplification, a number of inputs relating to physical constraints and boundary conditions to the SWAN model have been preselected. For the technical

assumptions imposed by the GUI for constructing the SWAN input file refer to [Hamilton 2001].

3.3 Running the SWANSURF Model

Once the input file has been created, the coupled model can be run. It can either be run directly after the input file has been created, or it can be run at a later stage. To run the coupled model immediately, just reply 'Yes' to the message that appears after the input file is created (Figure 16). To run the SWANSURF model at a later stage or using an input file created in a previous SWANSURF session, choose 'Run the SWANSURF Model' from the 'Options' menu or simply click on the icon. Click **File > Open** (or) to select the required project and then select **Run Model > Start** (or GO).

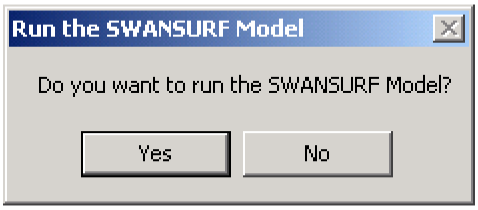


Figure 16: Message box appearing allowing the user to run SWANSURF straight after the input file has been created.

The time taken for the model to run is dependent on the size of the computational area, the input parameters (for example, whether single or multiple wave data is used), and the number of time steps. As the program runs, SWAN run-time output is written to the 'Print' file and screen output for both models is written to the 'screen' file.

After the coupled model is run, all outputs are stored in the project directory; that is, the directory where the SWAN input file was saved.

3.4 Model Outputs

The original GUI, which was developed to create the SWAN input file, was extended to allow the user to view the outputs produced by both the SWAN and SURF models. The raw data output files can be displayed (see Section 3.4.1 Viewing Reports). The GUI also converts these raw outputs into visual forms. In particular, the SWAN output can be viewed through the GUI as a map layer (see Section 3.4.3 Viewing Map Outputs) while the SURF output has been put into graphical format (see Section 3.4.2 Viewing Graphical Output) and in the form of a 'traffic light' system linked to various landing craft (see Section 3.4.4 Viewing 'Traffic Light' Output).

3.4.1 Viewing Reports

The GUI enables the user to view the output reports and the input files, by choosing **Options > View Files (Input, Data, and Output)** from the menu (or using the icon). Use the 'Open' icon ( ) to select the required file.

The SWAN output reports that can be viewed are the output tables, *_SWAN1D.tab and *_SWAN2D.tab, and the wave spectrum file, *_SWANSpec.out, where '*' represents the project name. The one-dimensional output table (*_SWAN1D.tab) contains data along the surf transect, while the two-dimensional output table (*_SWAN2D.tab) contains interpolated data for the entire computational area. Data elements contained in the tables consist of latitude and longitude coordinates (in degrees), x and y wind components (metres per second), depth (metres), significant wave height (metres), wave direction (degrees, clockwise from true North), and period (in seconds) for each computational time step. The one-dimensional table also includes distance offshore (in metres).

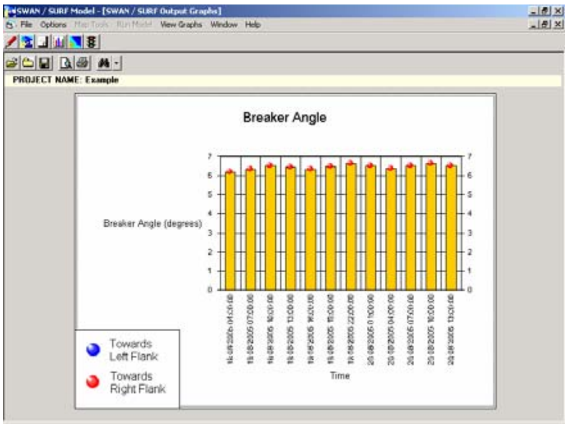
It should be noted that the SWAN depth output includes the bottom (datum) level plus water level (tides) but does not include wave-induced set-up on the shoreline (that is, the elevation in the mean water level as a result of wave breaking). This is due to the fact that set-up is not computed correctly by the SWAN program when spherical coordinates are used ([Booij *et al.* 2004] p70).

The SURF output consists of a detailed surf output report (*.out). The original SURF program outputs results in feet and knots. SWANSURF converts these results to metres and metres / second to make the SURF program compatible with SWAN. Therefore, the SURF output file shows SURF outputs converted to metres and metres per second. Furthermore, the results of this report have been summarised by the SWANSURF model in a plot data file (*.pdt). This file can be viewed through the GUI and is also used by the GUI to graph the SURF findings.

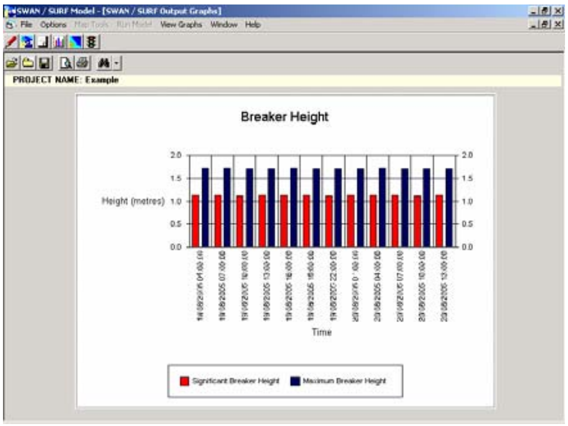
3.4.2 Viewing Graphical Output

The SWANSURF GUI was set up to plot the output generated by SURF, as summarised in the plot data file, *.pdt, where '*' is the project name. To access the graphical output viewer, choose **Options > View Visual Output > Graphs** or click on the icon. Then press **File > Open** ( ) and choose the graph data file (*.pdt) required. The types of graphs that can be displayed are to be found in the 'View Graphs' menu. The graphs available are breaker angle, breaker height, breaker type, depth profile (that is, bottom depth plus tides), longshore current, Modified Surf Index, significant wave height, number of surf lines, surf zone width, and wind.

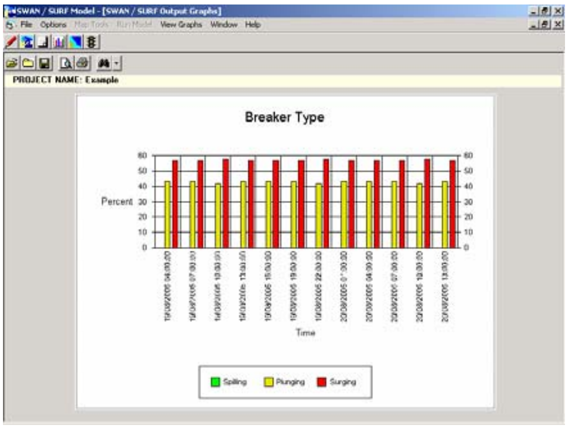
The following figures (Figure 17 (a)–(i)) show the graphical output obtained from a SWANSURF run. The data for these charts is obtained from the SURF model output.



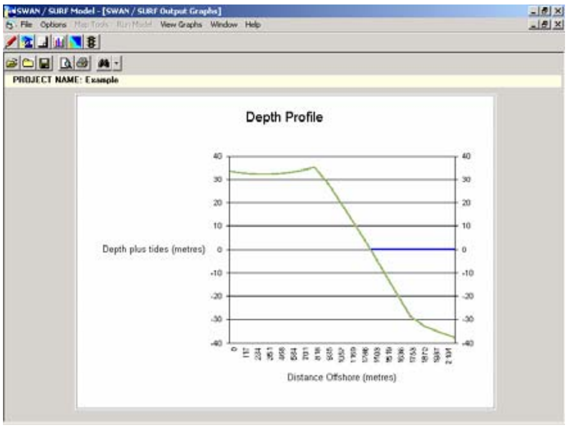
(a) Breaker Angle



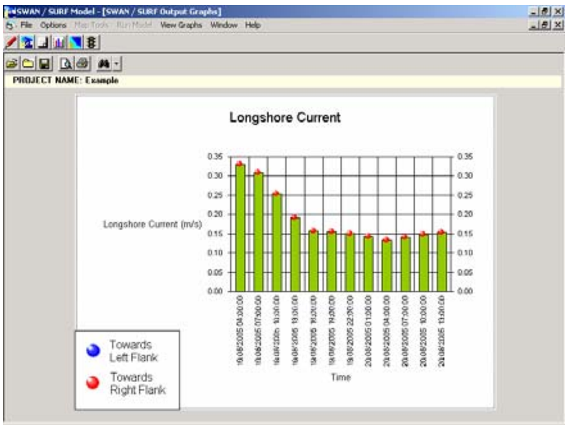
(b) Breaker Height



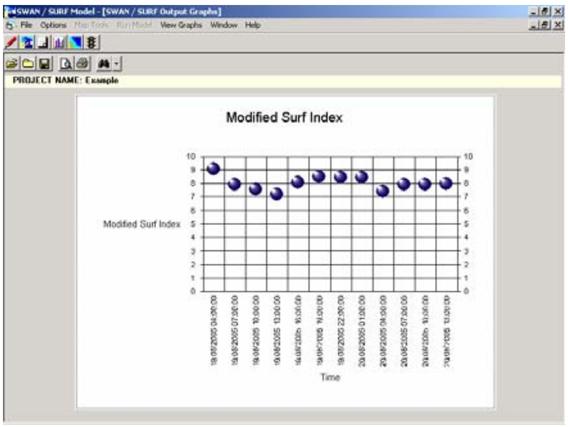
(c) Breaker Type



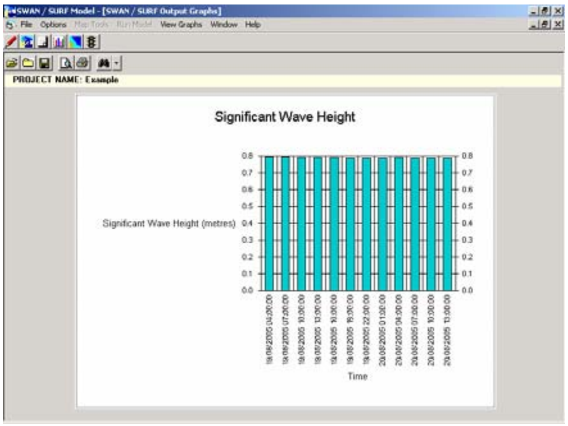
(d) Depth Profile



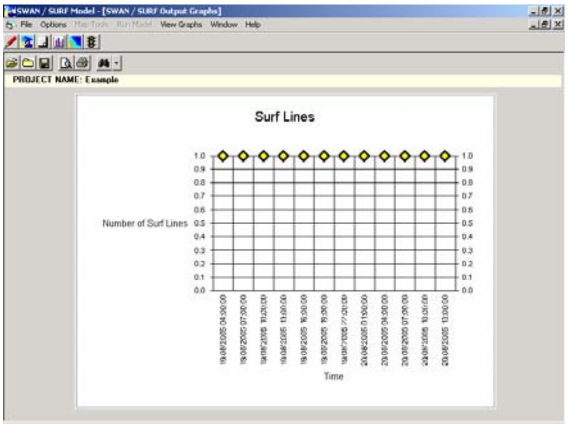
(e) Longshore Current



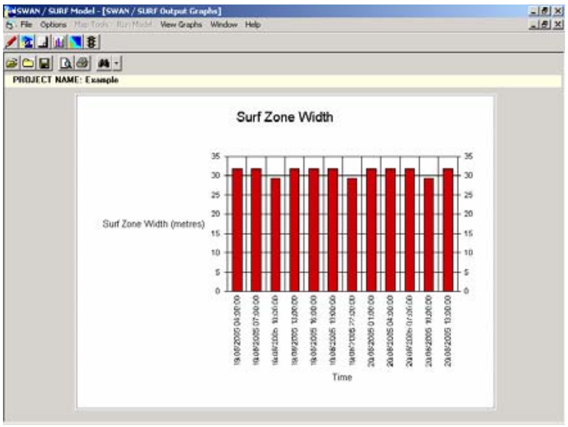
(f) Modified Surf Index



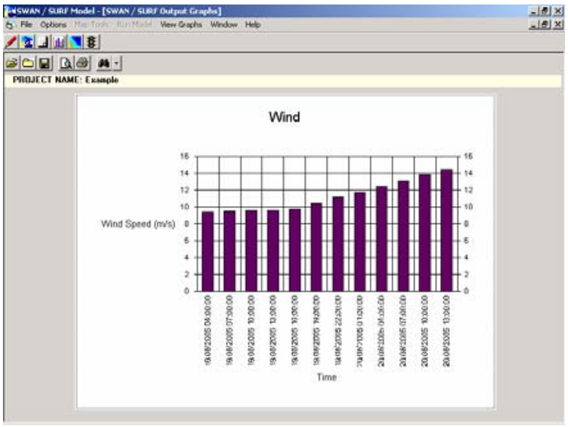
(g) Significant Wave Height



(h) Number of Surf Lines



(i) Surf Zone Width



(j) Wind

Figure 17: SURF output graphs.

3.4.3 Viewing Map Outputs

The GUI allows the SWAN tabular outputs to be displayed on a map in graphical form. This makes it easier for the user to visualise the bathymetry/topography and wave and wind conditions in the area of interest.

To view outputs on a map of the computational area, first click **Options > View Visual Output > Contour Plots** or alternatively, click on the icon. This will bring up a world map. Choose **Map Tools > Add Map Layer** from the menu or click on to add a chart to the map (for example, a SeaFarer chart). Alternatively, click on **Map Tools > Click a SeaFarer Tile to Load Chart Image** (icon) and then click on the predefined square to load a preloaded SeaFarer GeoTiff. The user is then able to add SWAN outputs on top of this map layer. To do this, choose **Map Tools > Create a Map Layer from a SWAN Output Table** or simply click . This will display an 'Open' dialogue box. Select the *.tab file for the project required. This will reveal a 'Choose Parameter' dialogue box from which the required parameter – namely, depth, wave height, wave

direction, wave period, wind speed or wind direction – and time step can be selected (Figure 18). Once ‘OK’ is pressed, an ESRI shapefile is created. To display this shape file on the map, select **Map Tools > Add SWAN Map Layer** or click  to select the required shape file (.sws).

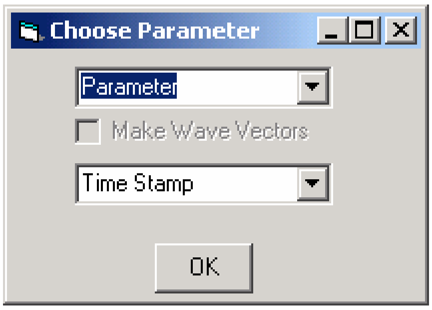
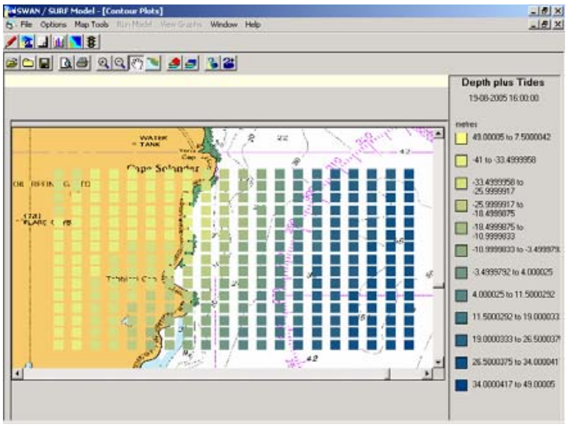


Figure 18: The ‘Choose Parameters’ dialogue box.

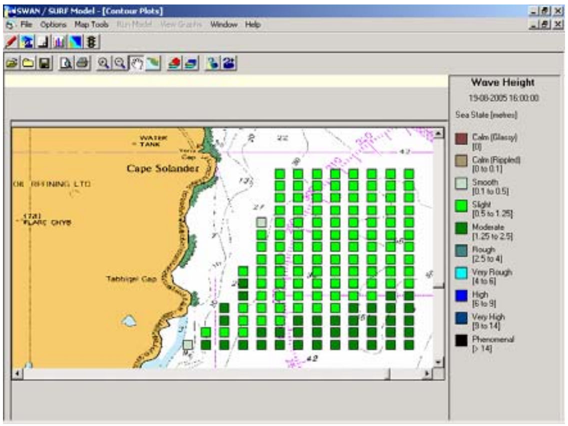
Figure 19 shows the map outputs for the example SWANSURF run. Figure 19 (a) represents the depth profile.

Figure 19(b) represents the wave heights. The wave heights are characterised according to sea state as defined in the Admiralty Manual of Navigation: Volume 2 [Great Britain. Royal Navy, 1960] (see Appendix D: Sea State Categories and the Beaufort Wind Scale for Contour Plot Output). Wave direction is depicted in Figure 19 (c) and is marked on the map with a ‘V’. Therefore, ‘V’ on the map would mean that the wave is coming from the North (0 degrees in Nautical convention). ‘<’ represents a wave coming from the East (90 degrees), ‘^’ is a wave coming from the South (180 degrees), and ‘>’ is a wave coming from the West (270 degrees). The map also includes any wave direction between these four cardinal points. A ‘.’ denotes a land value. (Note that the land values as represented by the SWAN output and the land values as represented by the GeoTiff do not always align due to the coarse bathymetry used.) Figure 19 (d) represents the wave period, which is simply characterised by a uniform split between the highest and lowest period.

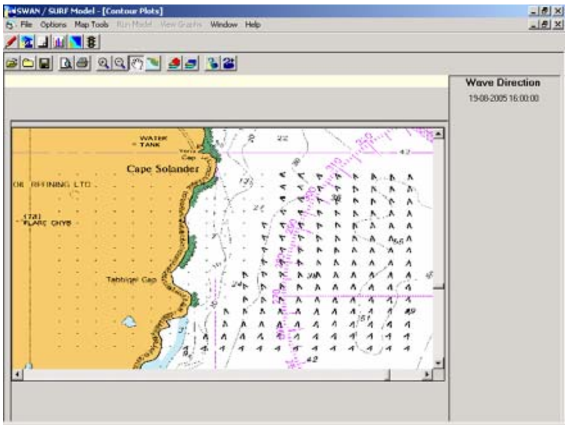
Figure 19 (e) represents the wind speed, categorised by the Beaufort scale as described in the Admiralty Manual of Navigation: Volume 2 [Great Britain. Royal Navy, 1960] (see Appendix D: Sea State Categories and the Beaufort Wind Scale for Contour Plot Output). Figure 19 (f) represents the wind direction. It is displayed in a similar fashion to the wave direction.



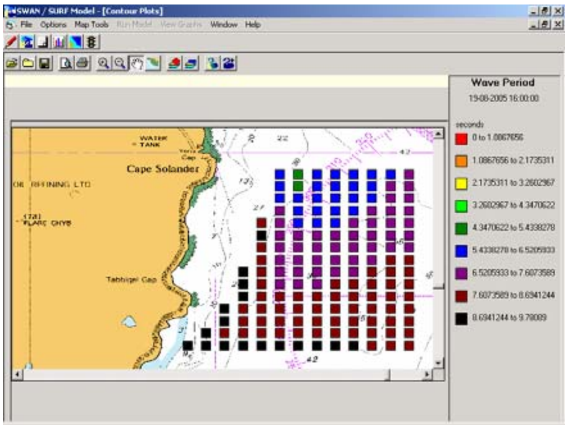
(a) Depth



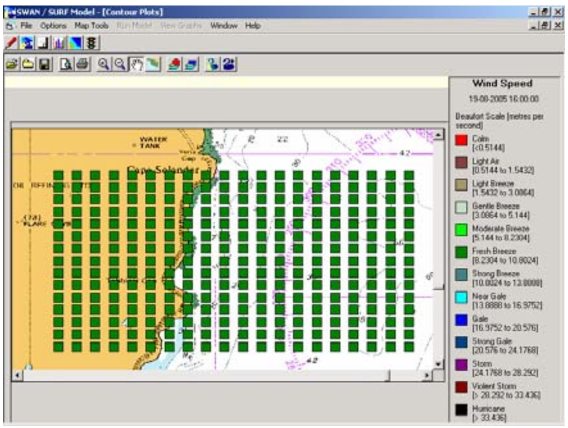
(b) Wave Height



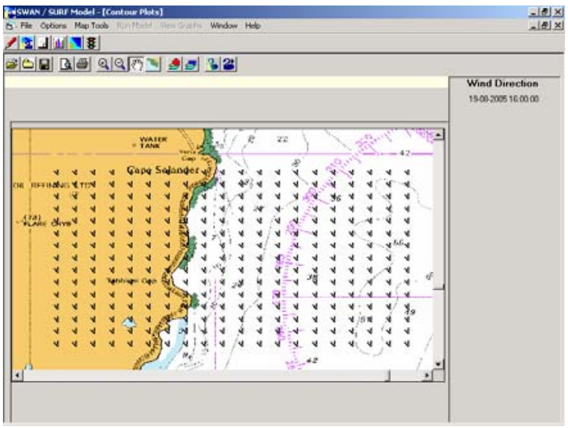
(c) Wave Direction



(d) Wave Period



(e) Wind Speed



(f) Wind Direction

Figure 19: SWAN map outputs.

Note that older versions of SWAN could produce graphical map outputs in HPGL format. These are not produced by the later version of SWAN (40.41) that forms part of the coupled model.

3.4.4 Viewing 'Traffic Light' Output

The GUI is able to create 'Traffic Light' output from the Modified Surf Index (MSI) value calculated by the SURF program. The MSI is a single dimensionless number that provides a summary of the surf conditions at a given time. A higher number means rougher conditions. Therefore, this index is a good indicator for the feasibility of performing landing operations with different types of landing craft. The safety of utilising a particular type of landing craft is dependent on the environmental conditions that can be effectively summarised using the MSI. Table 1 shows MSI cut off values for some classes of landing craft. These values are extracted from the US *Joint Surf Manual* [COMNAVSURFPAC/COMNAVSURFLANT 1987]. Note that some of the platforms listed are not part of the Royal Australian Navy fleet. This output should be updated to account for data pertaining to Australian amphibious platforms.

Table 1: Modified Surf Index limits for the safe landing of various craft.

Landing Craft	SAFE	CARE REQUIRED	UNSAFE
LCM8	MSI ≤ 7	7 < MSI ≤ 8	MSI > 8
LARC V	MSI ≤ 8	8 < MSI ≤ 9	MSI > 9
LCU	MSI ≤ 11	11 < MSI ≤ 12	MSI > 12
Pontoon	MSI ≤ 6	6< MSI ≤ 7	MSI > 7

The purpose of the 'traffic lights' output in the GUI is to show the user which sorts of landing craft may be used safely at a particular landing site, at a particular time, for particular environmental conditions. To access the traffic light output, click **Options > View Visual Output > Traffic Lights** or press and then open the required project. A coloured table is then displayed for each time step (the maximum is 26 time steps) and for various craft types (Figure 20). Green means safe, red is unsafe, while amber denotes that discretion is required. By referring to this output, the operator can tell at a glance the most appropriate landing craft for a given beach.

Note that the MSI enables the operator to ascertain the most feasible craft given the surf conditions for a particular landing site. However, the MSI does not take into account the skill level of personnel or the condition of the landing craft. These factors must be taken into consideration, especially when the MSI falls in the amber zone. The MSI is a single number representing a range of complex sea state conditions, and is a guide only.

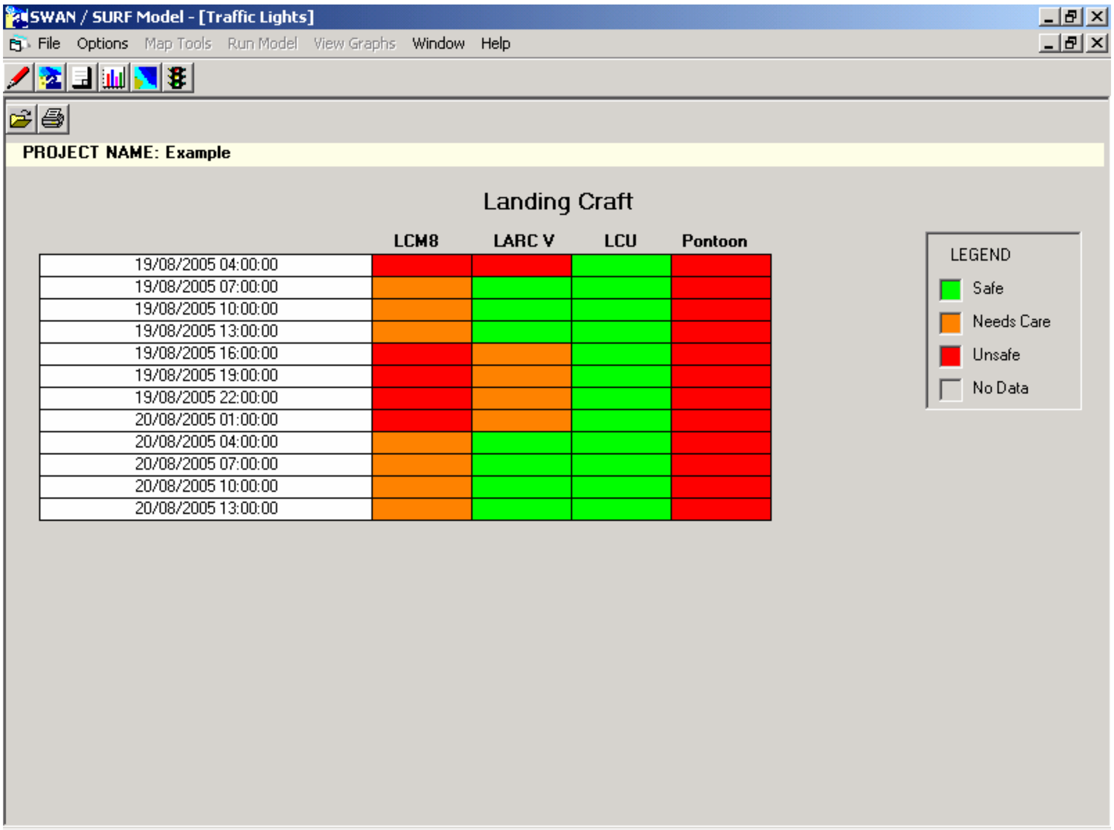


Figure 20: Traffic light outputs.

4. Potential Future Modifications

The SWAN program is continually updated by its authors at the Delft University of Technology to fix bugs discovered in the model and to improve the model physics. Therefore, the SWANSURF model can be kept current by upgrading the SWAN component of the model with the latest releases. This would require updating some of the SWANSURF model code. Although a newer version of SURF is available (SURF 3.2), SURF is no longer being updated.

A significant improvement to the current GUI would be an extension to allow the user to input wave data from larger-scale wave models, such as WAM.

Like all models, the accuracy of the outputs depends on the accuracy of the inputs. The SURF model accuracy is particularly dependent on the accuracy of the inputted nearshore bathymetry and offshore wave conditions. Having accurate forecasts is important in an operational context. Accurate forecasts are not only essential to ensure

that landing craft and personnel are not put into jeopardy; if the MSI is forecast higher than it actually is, options such as choice of landing craft could be restricted needlessly.

Mettlach and May [1997] studied the accuracy of SURF96 (an older version of SURF) with a particular emphasis on how the Modified Surf Index changed with respect to the input depth profile. By maintaining the accuracy of the wind, tides, and wave inputs, they were able to study the effects that different bathymetry profiles had on the model output. After analysing experimental results from 373 SURF runs, they concluded that the input bathymetry profile had a critical effect on the output produced.

Mettlach and May [1997] found that the Modified Surf Index accuracy depended largely on the age of the bathymetric profile used and the profile slope. Outdated bathymetric data led to fractional root-mean-square errors ranging from 19 to 44 per cent, while errors in depth profile slope estimation led to fractional root-mean-square errors ranging from 0 to 25 per cent. They discovered that in order to obtain results containing less than ten per cent error, the inputted depth profile had to be less than a day old and that the estimated slope should have less than ten per cent error. Simple sediment type-based depth profiles led to errors of 28 per cent. It is for this reason that the coupled model constructs a depth input file from actual bathymetry data to run the SURF model, rather than just specifying the sediment type.

Although Mettlach and May [1997] based their studies on a previous version of SURF, the importance of an accurate bottom profile is still current. Therefore, owing to the sensitivity of SURF to the bottom profile and the ever-changing nature of the sea floor due to wind and wave action, there is a need to constantly feed new bathymetry profiles into the SURF model to maintain accuracy. Consequently, it would be useful to incorporate a bottom sediment transportation model into the process for longer term forecasts. This would help provide more meaningful results. SWAN also needs accurate bathymetry to produce optimum results.

5. Acknowledgements

I would like to thank Les Hamilton from DSTO Pyrmont for all his help. Particularly for all his work setting up the original SWAN GUI from which parts of the 'Create SWAN Input File' code were borrowed. Also, Les provided the DLL code to create the spectrum files for the multiwave data.

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6. References

Andrew, C.J.F. (1999) *Bibliographic Review of Nearshore Wave Models*, DSTO-GD-0214, DSTO Aeronautical and Maritime Research Laboratory, Melbourne.

Booij, N., Haagsma, IJ.G., Holthuijsen, L.H., Kieftenburg, A.T.M.M., Ris, R.C., van der Westhuysen, A.J., Zijlema, M. (2004) *SWAN User Manual SWAN Cycle III Version 40.41*, Delft University of Technology, The Netherlands.

Commander, Naval Surface Force, Pacific, and Commander, Naval Surface Force, Atlantic (1987) *Joint Surf Manual*, COMNAVSURFPAC/COMNAVSURFLANTINST 3840.1B, Washington.

Earle, J.D. (1999) Applied and Operational Surf Modeling, *Shore and Beach* **67**(1) 70-75

Great Britain. Royal Navy, *Admiralty Manual of Navigation: Volume 2*, Her Majesty's Stationary Office, 1960.

Hamilton, L.J. (2001) *An Implementation Of The SWAN Wave Model For Non-experts Using A Simple Graphical User Interface*, DSTO Aeronautical and Maritime Research Laboratory, Melbourne. Unpublished Document.

Holthuijsen, L.H., Booij, N., Ris, R.C., Haagsma, IJ.G., Kieftenburg, A.T.M.M., Kriezi, E.E. (2000) *SWAN User Manual (not the short version) SWAN Cycle III Version 40.11*, Delft University of Technology, The Netherlands

Hsu, Y.L., Allard, R.A., Collins, M.J., Smith, J.M., Earle, M, and Miles, K. (1998) *Use of Coupled Numerical Wave and Surf Models to Simulate the Littoral Environment From Deep Water to the Beach*, NRL/FR/7322-98-9688 Naval Research Laboratory, Stennis Space Center, Mississippi.

Mettlach, T.R. and May, D.A. (1997) *The Accuracy of the Navy-Standard Surf Model – Derived Modified Surf Index and its Sensitivity to Nearshore Bathymetric Profile Errors*, NRL/FR/7240-97-9665, Naval Research Laboratory, Stennis Space Center, Mississippi.

Osieki, D.A., Migues, L.N., Earle, D.E., Hsu, Y.L. (2002a) *Software Design Document for the Oceanographic and Atmospheric Library SURF 3.1 Forecasting Program*, Neptune Sciences Inc., Louisiana, and Naval Research Laboratory, Stennis Space Center, Mississippi.

Osieki, D.A., Migues, L.N., Earle, D.E., Hsu, Y.L. (2002b) *Software Test Description for the Oceanographic and Atmospheric Library SURF 3.1 Forecasting Program*, Neptune Sciences Inc., Louisiana, and Naval Research Laboratory, Stennis Space Center, Mississippi.

Ris, R.C., Holthuijsen, L.H., and Booij, N. (1999) A Third-Generation Wave Model for Coastal Regions. Part II: Verification, *Journal of Geophysical Research* **104**(C4) 7667-7681

Thornton, E.B. and Guza, R.T. (1983) Transformation of Wave Height Distribution, *Journal of Geophysical Research* **88**(C10) 5925-5938

Thornton, E.B. and Guza, R.T. (1986) Surf Zone Longshore Currents and Random Waves, *Journal of Physical Oceanography* **16** 1165-1178

Woodham, R. H. (2005) *Applied GIS Handbook*, METOC Services Royal Australian Navy, Chapter 8 SWANSURF, 52-68 (Version 2, September 2005)

Appendix A: File Formats

A.1. Depth Data File (BathyTopo.bot)

The depth file that is created by the GUI (BathyTopo.bot) conforms to the standard SWAN format. It contains two header lines of the form:

BOTTOM REGULAR [xpinp] [ypinp] [alpinp] [mxinp] [myinp] [dxinp] [dyinp]
BOTTOM [factor] 'filename' 2 2 FORMAT '(F6.0)'

where xpinp and ypinp are the longitude and latitude of the lower left corner of the SWAN bottom input grid, alpinp is the direction of the x- axis of the bottom input grid (for the purpose of the GUI, this is always zero), mxinp and myinp are the number of meshes in the x and y directions (which is one less than the number of grid points in that direction), and dxinp and dyinp are the mesh sizes in the x and y directions of the bottom input grid. All data values are multiplied by 'factor'. In this file, consistent with both SWAN and SURF convention, depths are positive values while land elevations are negative. If the data had positive elevations and negative depths, then the factor would be '–1'. The first '2' in the second header line defines the way in which the data in the file is read. For this case, it indicates that the bottom values are input and read starting from the upper-left corner of the input grid and reading from left to right. The second '2' simply states that there are two header lines in the bottom file. '(F6.0)' is a Fortran format describing the structure of the data points. Following the two header lines is a single column of bathymetric and topographic data. SWANSURF records the data values in this column starting from the top left corner of the area under investigation reading the map from left to right. For more information regarding the bottom file format refer to the SWAN Manual ([Booij, 2004] pp 51 – 56).

A.2. Wind (WindSeries.dat) and Tide (TideSeries.dat) Files

The wind and tide files (WindSeries.dat and TideSeries.dat, respectively) are created when the user chooses the time series option for that particular parameter where data for each time step has been manually inputted. Their form mirrors that of the depth data file. There are two header lines in the file of the form:

INPGRID *Parameter* REGULAR [xpinp] [ypinp] [alpinp] [mxinp] [myinp] [dxinp] [dyinp] NONSTAT [tbeginp] [deltinp] *unit* [tendinp]
READINP *Parameter* [factor] 'filename' 2 2 FORMAT '(F6.0)'

Parameter is either WIND or WLEVEL depending on whether the data contained in the file refers to the wind or tide level. [tbeginp] is the start time of the data contained in the file while [tendinp] is the end time. Both start and end times are in the form

YYYYMMMDD.HHmmSS where YYYY is the year, MM is the month, DD is the day, HH is the hour, mm is the minutes, and SS is the seconds. The year is a four digit number. All other components of the date are two digit numbers. [deltinp] is the time interval of the data and *unit* is the unit with which this time interval is measured - either SEC for seconds, MIN for minutes, HR for hours, or DAY for days.

A single column of data for the chosen SWAN area, which is read from left to right starting at the top left corner, follows. Since this is a time series file, subsequent time step data is appended to the same file in the same format. It should be noted that the wind input that is written into the WindSeries.dat file is broken up into its x and y components with the x components written first for one time step, followed by the y component for that time step. Subsequent time step data is appended to the file following the same layout.

If the user elects to use the 'Data from a File' option in the 'Wind' or 'Tides' tab, then the file used must have this standard SWAN format.

A.3. Wave Spectrum File (WaveSpecFile.dat)

Figure 21 is an example of the wave spectrum file (WaveSpecFile.dat) in the required SWAN format. A brief description of the two-dimensional spectrum file follows.

'SWAN' Version number
'LONLAT' [for spherical coordinates] OR 'LOCATIONS' [for Cartesian coordinates]
Number of locations
Location coordinates

'AFREQ' [for absolute frequency] OR 'RFREQ' [for relative frequency]
Number of frequencies
Single column of frequencies in Hz

'CDIR'
Number of directions
Single column of directions in degrees

'QUANT'
Number of quantities
For each quantity: Name
Units
Exception Value

'FACTOR' OR 'ZERO' [if the spectrum is 0] OR 'NODATA' [if the spectrum cannot be computed (for instance, the spectrum would not be computed on land)]

The factor by which to multiply all values in the ensuing density table.
Scaled energy / variance densities.

If the user elects to use the 'Data from a File' option in the 'Wave Parameters' tab then the file must be in the spectrum file form described. For more information regarding the form of the SWAN wave spectrum file refer to the SWAN Manual ([Booij, 2004] pp 100-105).

```
SWAN   1
LONLAT
    1
      1.00        1.00
AFREQ
   32
 0.04000
 0.04438
 0.04923
 0.05462
 0.06060
 0.06723
 0.07458
 0.08274
 0.09179
 0.10184
 0.11298
 0.12534
 0.13906
 0.15427
 0.17115
 0.18988
 0.21066
 0.23371
 0.25928
 0.28765
 0.31912
 0.35404
 0.39278
 0.43575
 0.48343
 0.53633
 0.59501
 0.66012
 0.73235
 0.81248
 0.90138
 1.00000
CDIR
   36
   5.0
  15.0
  25.0
  35.0
  45.0
  55.0
  65.0
  75.0
  85.0
  95.0
 105.0
 115.0
 125.0
 135.0
 145.0
 155.0
 165.0
 175.0
 185.0
 195.0
 205.0
 215.0
 225.0
 235.0
 245.0
 255.0
```

```
 265.0
 275.0
 285.0
 295.0
 305.0
 315.0
 325.0
 335.0
 345.0
 355.0
QUANT
   1
VaDens
m2/Hz/degr
  -1.0
FACTOR
     9.4074869E-07
   53  283  372  123    9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    2
  542  2871  3775  1254    98    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0   22
 2097 11103 14600  4851   379    5    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0   88
 4293 22729 29887  9931   824  410  1000   796   197    14    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    1  180
 5775 30572 40199 13365  1328  2395  5971  4751  1180    83    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    1  242
 5887 31165 40979 13640  1856  6665 16692 13280  3300   233    3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    1  247
 4997 26457 34789 11615  2745 15482 38829 30892  7678   544    9    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    1  210
 3760 19904 26173  8841  5422 39845 99998 79556 19773  1401    23    0    0    0    0    0    0    0    0    1    3    3    1    0    0    0    0
0    0    0    0    0    0    0    1  158
 2612 13827 18182  6118  2987 21131 53027 42187 10485   743    12    0    0    0    0    0    0    0    4   23   54   54   23    4    0    0
0    0    0    0    0    0    0    0    0  109
 1721  9113 11983  4015  1433  9428 23655 18819  4677   331    5    0    0    0    0    0    0    1   22  128  297  297  128   22    1    0
0    0    0    0    0    0    0    0    0   72
 1095  5800  7627  2557   961  6412 16089 12800  3181   225    3    0    0    0    0    0    0    3   61  342  789  789  342   61    3    0
0    0    0    0    0    0    0    0    0   46
  681  3608  4745  1592   637  4325 10852  8633  2145   152    2    0    0    0    0    0    0   10  150  829  1902  1897  821  146    9    0
0    0    0    0    0    0    0    0    0   28
  417  2211  2907   976   408  2796  7016  5582  1387    98    1    0    0    0    0    0    1   36  402  2039  4537  4471  1925  341   22    0
0    0    0    0    0    0    0    0    0   17
  253  1341  1764   592   255  1757  4410  3508   872    61    1    0    0    0    0    0    6   78  461  1523  2708  2391  974  167   10    0
0    0    0    0    0    0    0    0    0   10
  152   808  1063   357   156  1084  2721  2164   538    38    0    0    0    0    0    0   15  173  824  1968  2528  1738  598   92    5    0
0    0    0    0    0    0    0    0    0    6
   91   485   637   214    95   660  1658  1319   327    23    0    0    0    0    0    1   40  429  1941  4179  4564  2568  720   92    4    0    0
0    0    0    0    0    0    0    0    3
   54   290   381   128    57   399  1002   797   198    14    0    0    0    0    0    2   78  831  3709  7755  8013  4130  1026  113    4    0
0    0    0    0    0    0    0    0    0    2
   32   173   227    76    34   240   602   479   119     8    0    0    0    0    0    1   32  351  1572  3315  3481  1843  477   55    2    0    0
0    0    0    0    0    0    0    0    1
   19   103   135    45    20   143   361   287    71     5    0    0    0    0    0    0   16  180  811  1719  1824  981  259   31    1    0    0    0
0    0    0    0    0    0    0    0
   11    61    81    27    12    86   215   171    42     3    0    0    0    0    0    0   11  124  559  1181  1246  664  173   20    0    0    0    0
0    0    0    0    0    0    0    0
    6    36    48    16     7    51   128   102    25     1    0    0    0    0    0    0    7   83  372  785  824  436  112   13    0    0    0    0    0
0    0    0    0    0    0    0
    4    21    28     9     4    30    76    61    15     1    0    0    0    0    0    0    5   53  238  502  526  277   71    8    0    0    0    0    0    0
0    0    0    0    0    0
    2    13    17     5     2    18    45    36     9     0    0    0    0    0    0    0    3   33  149  313  328  172   44    5    0    0    0    0    0    0
0    0    0    0    0    0
    1     7    10     3     1    10    27    21     5     0    0    0    0    0    0    0    1   20   91  192  201  105   26    3    0    0    0    0    0    0
0    0    0    0    0    0
    0     4     6     2     0     6    16    12     3     0    0    0    0    0    0    0    1   12   55  117  122   64   16    1    0    0    0    0    0    0
0    0    0    0    0    0
```

```
   0   2   3   1   0   3   9   7   1   0   0   0   0   0   0   0   0   7  33  70  73  38   9   1   0   0   0   0   0   0   0
0   0   0   0   0
   0   1   2   0   0   2   5   4   1   0   0   0   0   0   0   0   0   4  20  42  44  23   5   0   0   0   0   0   0   0   0
0   0   0   0   0
   0   0   1   0   0   1   3   2   0   0   0   0   0   0   0   0   0   2  12  25  26  13   3   0   0   0   0   0   0   0   0
0   0   0   0   0
   0   0   0   0   0   0   2   1   0   0   0   0   0   0   0   0   0   1   7  15  15   8   2   0   0   0   0   0   0   0   0
0   0   0   0
   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   4   9   9   4   1   0   0   0   0   0   0   0   0
0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   2   5   5   2   0   0   0   0   0   0   0   0   0
0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   3   3   1   0   0   0   0   0   0   0   0   0
0   0   0   0
```

Figure 21: An example of the SWAN spectrum file.

A.4. SWAN Input Files

Figure 22 and Figure 23 show the form of the two SWAN input files that are created by the SWANSURF GUI. Whenever the multiple data option for waves is used, the SWANSURF model sets up two input files. One is the ‘hot’ input file (Figure 22), *.inh, which is used to run the standalone SWAN model in stationary mode to produce the ‘hotfile’. The second input file is the standard SWAN input file, *.inp, which is used to run the SWANSURF model (Figure 23) in dynamic (nonstationary) mode with the ‘hotfile’ as the initial condition for the wave input field.

```
PROJ 'Example' '1' 'INPUT TO SWAN WAVE MODEL'
MODE STATIONARY TWODIMENSIONAL
COORD SPHE QC
CGRID REGULAR 151.2188889 -34.0316667 0 0.0266667 0.0130556 19 14 CIRCLE 36 0.04 1 31
SET NAUTICAL
INPGRID BOTTOM REGULAR 151.1888889 -34.0616667 0 9 7 0.01 0.01
READINP BOTTOM 1 'C:\SWANSURF_Proj\BathyTopo.bot' 2 2 FORMAT '(F6.0)'
BOUNDSPEC SIDE NORTH CONSTANT FILE 'C:\SWANSURF_Proj\WaveSpecFileN.dat'
BOUNDSPEC SIDE EAST CONSTANT FILE 'C:\SWANSURF_Proj\WaveSpecFileE.dat'
BOUNDSPEC SIDE SOUTH CONSTANT FILE 'C:\SWANSURF_Proj\WaveSpecFileS.dat'
BOUNDSPEC SIDE WEST CONSTANT FILE 'C:\SWANSURF_Proj\WaveSpecFileW.dat'
WIND 9.4 170
SET LEVEL 0.1
FRICTION JONSWAP 0.067
QUAD
SET MAXERR 2
$
PROP BSBT
NUMERIC ACCUR NONST 30 DIRIMPL 0.5 4
$
TABLE 'COMPGRID' HEAD 'Example_HOTSWAN2D.tab' XP YP WIND DEP HSIGN DIR
TM01
$
TEST 0,0
COMPUTE
$
HOTF 'Example.hot'
$
STOP
$
```

Figure 22: The hot input file (.inh) generated by the SWANSURF GUI. This input file is used to create the wave spectrum hotfile. The hotfile will, in turn, provide the initial wave field to run the SWANSURF model.*

```
PROJ 'Example' '1' 'INPUT TO SWAN WAVE MODEL'
MODE DYNAMIC TWODIMENSIONAL
COORD SPHE QC
CGRID REGULAR 151.2188889 -34.0316667 0 0.0266667 0.0130556 19 14 CIRCLE 36 0.04 1 31
SET NAUTICAL
INPGRID BOTTOM REGULAR 151.1888889 -34.0616667 0 9 7 0.01 0.01
READINP BOTTOM 1 'C:\SWANSURF_Proj\BathyTopo.bot' 2 2 FORMAT '(F6.0)'
INIT HOTS 'Example.hot'
$
INPGRID WIND REGULAR 151.2188889 -34.0316667 0 19 14 0.0014035 0.0009325 NONSTAT
20050819.040000 3 HR 20050820.130000
READINP WIND 1 'C:\SWANSURF_Proj\WindSeries.dat' 2 2 FORMAT '(F6.1)'
INPGRID WLEVEL REGULAR 151.218889 -34.031667 0 19 14 0.001404 0.000933 NONSTAT
20050818.040000 6 HR 20050820.220000
READINP WLEVEL 1 'C:\SWANSURF_Proj\TideSeries.dat' 2 2 FORMAT '(F6.1)'
FRICTION JONSWAP 0.067
QUAD
SET MAXERR 2
$
PROP BSBT
NUMERIC ACCUR NONST 30 DIRIMPL 0.5 4
$
TABLE 'COMPGRID' HEAD 'Example_SWAN2D.tab' XP YP WIND DEP HSIGN DIR TM01
OUTPUT 20050819.040000 3 HR
CURVE 'Transect ' 151.22 -34.0247222 735 151.2430556 -34.0194444
TABLE 'Transect ' HEAD 'Example_SWAN1D.tab' XP YP WIND DEP HSIGN DIR TM01 DIST
OUTPUT 20050819.040000 3 HR
SPECOUT 'Transect ' SPEC2D ABS 'Example_SWANSpec.out'  OUTPUT 20050819.040000 3 HR
$
TEST 0,0
COMPUTE NONSTAT 20050819.040000 3 HR 20050820.130000
STOP
$
```

Figure 23: The SWAN input file (.inp) created by the GUI to run the multi-step SWANSURF model.*

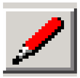
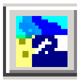
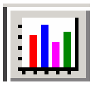
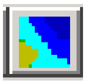
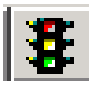
Appendix B: SWANSURF Model Installation

All files required to operate SWANSURF are included in the setup package and are placed in the required directories when the setup wizard is activated. The SWANSURF executable program, SWANSURF.exe, will be placed in the directory C:\Program Files\SWANSURF. To run the program, simply open the SWANSURF.exe file.

Appendix C: SWANSURF GUI Toolbar Buttons

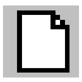
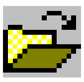
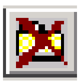
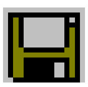
C.1. GUI Start Up

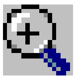
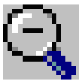
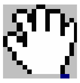
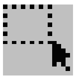
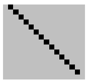
Table 2: The SWANSURF GUI start up toolbar.

Toolbar Button	Purpose
	Create a new SWAN input file or view an existing SWAN input file.
	Run SWANSURF.
	View the output reports produced by the SWAN and SURF models.
	View output graphs produced from SURF output data.
	View contour plots on a map.
	View 'traffic lights' graphical table created from SURF output.

C.2. Create SWAN Input File

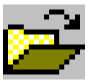
Table 3: The 'Create SWAN Input File' toolbar.

Toolbar Button	Purpose
	Create a new SWAN input file.
	Open and view an existing SWAN input file.
	Delete SWAN data from input text boxes.
	Save data.

	Print.
	Zoom in.
	Zoom out.
	Pan.
	Select the SWAN computational area.
	Draw the surf transect on the map.
	Click on a predefined box on the map to load a SeaFarer tile.
	Add a map layer (either a GeoTiff or a shapefile).

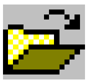
C.3. Run SWANSURF

Table 4: The 'Run SWANSURF' toolbar.

Toolbar Button	Purpose
	Open the SWAN input file (*.inp) associated with the project that is to be run.
	Run the SWANSURF model.

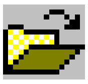
C.4. View Output Reports

Table 5: The 'View Output Reports' toolbar.

Toolbar Button	Purpose
	Open the SWAN and SURF output files (*.out, *.tab, *.pdt) of the desired project.

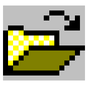
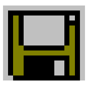
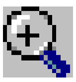
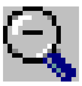
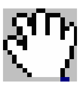
C.5. View Graphs

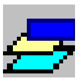
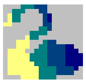
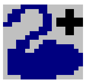
Table 6: The 'View Graphs' toolbar.

Toolbar Button	Purpose
	Open the SWAN and SURF graph data output file (*.pdt) of the desired project.
	Print graph.

C.6. View Contour Plots

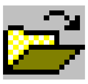
Table 7: The 'Contour Plots' toolbar.

Toolbar Button	Purpose
	Open required project.
	Save current contour plot display.
	Print the map area.
	Zoom in.
	Zoom out.
	Pan.

	Click on a predefined box on the map to load a SeaFarer tile.
	Add a map layer (either a GeoTiff or a shapefile).
	Remove a map layer from the map.
	Create a map layer from a SWAN output table.
	Add SWAN Map Layer.

C.7. View Traffic Lights

Table 8: Traffic Lights form toolbar buttons.

Toolbar Button	Purpose
	Open the SWAN and SURF graph data output file (*.pdt) of the desired project.

Appendix D: Sea State Categories and the Beaufort Wind Scale for Contour Plot Output

D.1. Sea State Categories

The contour plot output of the wave heights is categorised according to sea state as follows (reproduced from [Great Britain. Royal Navy, 1960]):

Table 9: Sea state categories according to wave height. (Reproduced from [Great Britain. Royal Navy, 1960])

Number	Height (metres)	Description	Effect
0	0	Calm (glassy)	No wave breaking on beach.
1	0 – 0.1	Calm (rippled)	No wave breaking on beach.
2	0.1 – 0.5	Smooth	Slight wave breaking on beach.
3	0.2 – 1.25	Slight	Wave rocks buoys and small craft.
4	1.25 – 2.5	Moderate	Sea becoming furrowed.
5	2.5 – 4	Rough	Sea deeply furrowed.
6	4 – 6	Very rough	Sea much disturbed with rollers having steep fronts.
7	6 – 9	High	Sea much disturbed with rollers having steep fronts (damage to foreshore).
8	9 – 14	Very high	Towering seas.
9	Over 14	Phenomenal	Precipitous seas (experienced only in hurricanes).

D.2. Beaufort Wind Scale

The contour plot output of the wind speed is categorised according to the Beaufort wind scale [Great Britain. Royal Navy, 1960]:

Table 10 Beaufort wind scale. (Reproduced from [Great Britain. Royal Navy, 1960])

Wind Force (Beaufort)	Speed (knots)	Speed (metres/second) *	Description
1	< 1	< 0.51	Calm
2	1-3	0.51 - 2.06	Light air
3	4-6	2.06 - 3.60	Light breeze
4	7-10	3.60 - 5.66	Gentle breeze
5	11-16	5.66 - 8.74	Moderate breeze
6	17-21	8.74 - 11.32	Fresh breeze
7	22-27	11.32 - 14.40	Strong breeze
8	28-33	14.40 - 17.49	Near gale
9	34-40	17.49 - 21.09	Gale
10	41-47	21.09 - 24.69	Strong gale
11	48-55	24.69 - 28.81	Storm
12	56-65	28.81 - 33.95	Violent storm
13 **	66-71	33.95 - 37.04	Hurricane
14	72-80	37.04 - 41.67	-
15	81-89	41.67 - 46.30	-
16	90-99	46.30 - 51.44	-
17	100-108	51.44 - 55.56	-

* This column is not reproduced from [Great Britain. Royal Navy, 1960]. The conversions were made by multiplying the speed in knots by 0.5144.

** In the GUI, the 'Contours' form combines categories 13, 14, 15, 16, and 17 for display purposes.

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Georgette Christie

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19. ABSTRACT

This report describes the implementation and usage of 'SWANSURF', a graphically-driven program for the modelling of waves and surf conditions in the littoral, in support of amphibious operations. The program is based on a coupling of the SWAN (Simulating Waves Nearshore) model developed by the Delft University of Technology and the SURF model (or the Navy Standard Surf Model) developed by the US Navy. The Graphical User Interface provides a platform that allows the user to easily enter inputs, run the coupled models, view the results and forecast the potential impacts of the conditions on amphibious and other littoral operations.

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